RELATIONES ANNUAE INSTITUTI GEOLOGICI PUBLICI HUNGARICI

A MAGYAR ÁLLAMI FÖLDTANI INTÉZET

ÉVI JELENTÉSE

1992–1993/II.

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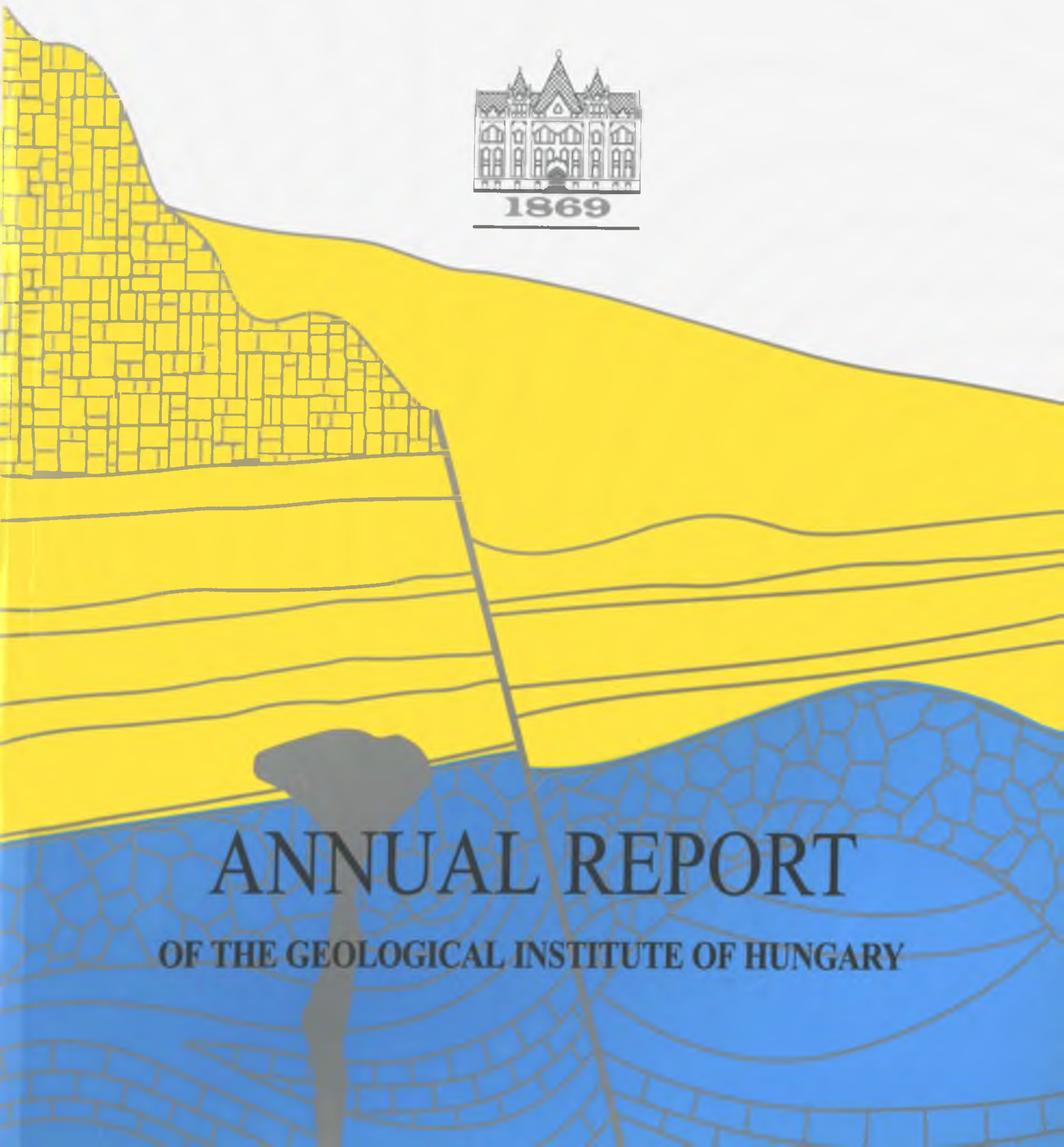

ANNUAL REPORT

OF THE GEOLOGICAL INSTITUTE OF HUNGARY

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BUDAPEST, 1999

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Published by the Geological Institute of Hungary — kiadja a Magyar Állami Földtani Intézet

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HU ISSN 0368–9751

CONTENTS

TARTALOM

A M. ÁLL. FÖLDTANI INTÉZET ÉVI JELENTÉSE, 1992–1993/II. 5–8 (1999)

BÚCSÚ KISS ÁRPÁDTÓL

DUDICH ENDRE és HÁLA JÓZSEF
Magyar Állami Földtani Intézet, 1143 Budapest, Stefánia út 14.

Nagy és fájdalmas veszteség érte Intézetünket 1993-ban: július 26-án, életének 48. évében elhunyt KISS ÁRPÁD könyvtáros és szakfordító. Családtagjai, munkatársai és barátai augusztus 6-án vettek Tőle végső búcsút a Farkasréti temetőben.

KISS ÁRPÁD 1946. február 13-án született Budapesten. Az általános és a középiskolát a fővárosban végezte el, a Fazekas Mihály Gimnáziumban érettségizett 1964-ben. 1964 októberétől 1965 júniusáig, az Országos Széchényi Könyvtárban dolgozott, kezdetben mint raktáros, később mint a Bibliográfiai Osztály munkatársa. 1965-től az Eötvös Loránd Tudományegyetem Bölcsészettudományi Karán, angol–könyvtár szakon folytatta tanulmányait, közben 1969. szeptember 15-étől 1970. július 30-áig az Építéstudományi Intézetben dolgozott könyvtárosként. Az egyetemen 1970-ben kapott könyvtárosi, valamint angol nyelv és irodalom szakos középiskolai tanári diplomát.

1970. augusztus 1-jétől a miskolci Nehézipari Műszaki Egyetem Központi Könyvtárának munkatársa volt, ahol a különgyűjteményeket gondozta, részt vett a Selmeci Műemlékkönyvtár anyagát feltáró katalógus összeállításában és szerkesztésében, megbízott csoportvezetőként a kurrens könyvanyag feldolgozását irányította és a betűrendes katalógust szerkesztette, részese volt a könyvtárban folyó, a hazai ásványi nyersanyagok kutatásának és kitermelésének történetét feldolgozó kutatómunkának, és szaktájékoztatói munkakört is betöltött. 1975-ben főkönyvtárosi kinevezést kapott, 1978-tól az egyetem angol nyelvű folyóiratanyagának beszerzése, nyilvántartása és feldolgozása is a feladatai közé tartozott. 1979 szeptemberétől Gombocz István-ösztöndíjjal a Kent State University-n (Kent, Ohio, USA) tanult, ahol 1980 augusztusában „Master of Library Science” diplomát kapott.

KISS ÁRPÁDot 1981. február 1-jén nevezték ki a Magyar Állami Földtani Intézet szakkönyvtárának a vezetőjévé. Könyvtárvezetői tevékenysége során eredményesen szervezte és irányította a gyűjteményben folyó munkát és több módszertani korszerűsítést is kezdeményezett, illetve hajtott végre: gyarapodási jegyzékek és a kurrens folyóiratok jegyzékeinek összeállítása és közzététele, az Intézetben készült szakfordítások feltárása és összegyűjtése, az 1957–1985 között megjelent intézeti szöveges

KISS ÁRPÁD
1946–1993

kiadványok katalógusának elkészítése stb. 1983-ban megfogalmazta a „Magyarország földtani bibliográfiája” című kutatási programot, 1984-től e program felelőse és tevékeny közreműködője volt. A tárolási, anyagmozgatási és állománykezelési nehézségek ellenére biztosította a Könyvtár zavartalan működését, emellett kiállításokat rendezett és rendszeresen részt vett az Intézet története és tevékenysége iránt érdeklődők tájékoztatásában. 1986-ban a Könyvtártudományi és Módszertani központ által a közművelődési könyvtárak szaktájékoztatói részére szervezett továbbképző tanfolyamon a földtudományokra vonatkozó rész előadója volt. Tevékenyen részt vett az Intézet által szervezett nemzetközi rendezvények előkészítésében és megvalósításában is. Az Intézet feladatainak teljesítése érdekében végzett munkájáért 1988-ban igazgatói dicséretben részesült. Eredményesen ápolta a Könyvtár nemzetközi kapcsolatait, ennek egyik elismerése volt, hogy a bécsi Geologische Bundesanstalt

1989-ben, „a jó együttműködéssel kapcsolatos köszönet kifejezéseként", levelező tagjává választotta. Könyvtárvezetőként 1991-ig tevékenykedett az Intézetben, az év július 24-étől a Kiadói és Szerkesztőségi Osztály munkatársaként szakfordítói munkát végzett haláláig.

KISS ÁRPÁD felsőfokú nyelvtudásával nagy hasznára volt Intézetünknek. 1982-től éveken keresztül angol nyelvtanfolyamokat vezetett. Számos munkatársunk Tőle tanulta meg e nyelv alapjait, többeket nyelvvizsgához segített. Konferenciákon, tárgyalásokon tolmácsolt, az Intézetbe látogató külföldi vendégeket kalauzolta. Több éven át részt vett az Évi Jelentés elkészítésében: rezüméket és tanulmányokat fordított, illetve az utóbbiak szakozását végezte. Nyelvi lektora volt a *Contributions to the History of Geological Mapping* (szerk.: DUDICH ENDRE; Bp., 1984) és a *Neogene Mineral Resources in the Carpathian Basin, Historical Studies on their Utilization* (szerk.: HÁLA JÓZSEF; Bp., 1985) című tanulmányköteteknek, fordítói munkáját pl. az alábbi művek dicsérik: *Rocks, Fossils and History, Italian–Hungarian Relations in the Field of Geology* (szerk.: HÁLA JÓZSEF; Bp., 1987), *The Role of János Böckh and Hugó Böckh in the Hungarian Geology* (szerző: VITÁLIS GYÖRGY; Bp., 1991), *Museums and Collections in the History of Mineralogy, Geology and Paleontology in Hungary* (szerk.: VITÁLIS GYÖRGY és KECSKEMÉTI TIBOR; Bp., 1991). Szakirodalmi munkásságából kiemelendő a DRAHOS ISTVÁNNÉval és TARJÁN ANDRÁSsal összeállított katalógus az egykori selmeci bányászati akadémia műemléki könyvtáráról, valamint a ROBERT TOWNSON és EDWARD DANIEL CLARK magyarországi utazásait és azok földtani–bányászati vonatkozásait bemutató két tanulmány.

A tudomány nem lehet meg könyvek, jól szervezett és szakszerűen működő könyvtárak nélkül. Különösen élénken átérezzük ezt mostanában, amikor újra nehézzé vált beszerezni a külföldi szakirodalmat. Az új információáradat túlnyomó része ma már angol nyelvű — akár tetszik ez nekünk, akár nem. Ha azt akarjuk, hogy tudományos eredményeinket a külvilág tudomásul vegye, angolul (vagy legalább angolul is) közzé kell tennünk azokat. A soha kellően meg nem becsült könyvtárosi és fordítói munka ritkán látványos, de mindig hálátlan. Az akarva-akaratlanul önző és gyakorta türelmetlen szakemberek legtöbbször csak azt veszik észre, ha egy keresett könyv nincs meg, éppen most nem hozzáférhető, az igényelt, és persze sürgős fordítás lassabban készül a megkívántnál, ha az elkészült fordítás túl szolgaian követi az eredetit és ezért „heavy handed", nehézkes vagy ellenkezőleg, túl szabadon kezelte azt és így inkább ferdítés, mint fordítás. Ilyenkor a leggondosabb, legszorgalmasabb munkát sem ismerik el mentségnek. KISS ÁRPÁD ezeken a területeken munkálkodott, mintegy a tudomány árnyékában. Fordításait számos külföldi szakember illette elismeréssel.

KISS ÁRPÁDdal gyakorlott könyvtárost és szakfordítót, nagy műveltségű, mindenkor segítőkész embert, kollégát és barátot veszítettünk el. Mélységesen szomorú dolog, hogy nem voltunk képesek jobban a segítségére lenni, eredményesen állni mellette, amikor egyéni problémáival küzdött. Ezekről, ha beszélt is nagy ritkán, ezt mindig enyhén önironikus „understatement"-el, alulértékeléssel tette és ez olykor bizony megtévesztő volt. Amikor segíteni akartunk Neki, türelmesen meghallgatta aggódó szavainkat — és ment tovább a maga választotta rögös úton. Most, amikor többé már nem tehettünk érte semmit, legalábbis köznapi, evilági értelemben nem, búcsúzóul hadd idézzünk négy sort egyik kedves amerikai költőjének, H. W. LONGFELLOWnak „Az élet zsoltára" verséből:

Valós az élet! Komoly az élet!
Célja nem lehet a sír;
Porból vagy és porrá leszel,
A lélekről nem szól a hír.

Isten Veled!

FAREWELL TO ÁRPÁD KISS

by ENDRE DUDICH and JÓZSEF HÁLA

Geological Institute of Hungary, H–1143 Budapest, Stefánia út 14.

Our Institute suffered a great and painful loss in 1993: ÁRPÁD KISS, librarian and professional translator, secondary school teacher of the English language and literature left us forever. He died on 26th July, 1993, aged 47.

He began his career in the National Széchényi Library (1969–1970), later on he changed this post for one in the Central Library of the Technical University of Heavy Industry in Miskolc (1970–1981). There he took part in the compilation and editing of the Analytical Catalogue of the "Monument-Library" owned by the one-time Mining Academy in Selmecbánya, moreover participated in the research on the prospection and exploitation history of the domestic raw-materials. Sponsored by the "Gombocz István Scholarship" from 1979 on he was reading for a degree of "Master of Library Science" at the Kent State University (Kent, Ohio, USA). He obtained this degree in 1980.

ÁRPÁD KISS was appointed to be chief librarian of the Hungarian Geological Institute on the 1st February 1981. Here he iniciated several technical improvements, among them the publication of lists of accessions and current periodicals, the collection of the scientific translations done in the Institute, the compilation of a catalogue of the Institute's publications embracing the 1957–1985 period to mention just a few here. In 1983 he drafted the research programme of the "Geological Bibliography of Hungary"; from 1984 on he was charged with the organization of these activitites and also took part in their realization. In spite of the difficulties of storage and handling of the stock he managed to operate the services of the library without any perceptible inconvenience to its users, organized exhibitions and regularly gave detailed information to those interested in the history and various activities of the Institute. He gave lectures at the postgraduate course arranged by the Centre for Library Science and Methodology on subjects related to the earth sciences. He took active part in the preparation and execution of international programmes of the Institute.

For his outstanding activity he was awarded the "Directorial Appreciation" in 1988. The international connections of the library were fostered successfully by him; this activity was recognized by the Geologische Bundesanstalt of Vienna by electing him corresponding member "as the expression of esteem for good cooperation". He held the post of head librarian till 1991; subsequently he was working as a scientific translator until his death.

ÁRPÁD KISS's high proficiency in English was been of outstanding value for our Institute. For many years he conducted English courses, interpreted at conferences and discussions, guided foreign guests paying visit to the Institute. The linguistic checking of the studies entitled *Contributions to the History of Geological Mapping* (edited by E. DUDICH, Budapest, 1984) and *Neogene Mineral Resources in the Carpathian Basin, Historical Studies on their Utilization* (edited by J. HÁLA, Budapest, 1985) was performed by him. His activity as a professional translator is represented by the following publications: *Rocks, Fossils and History, Italian–Hungarian Relations in the Field of Geology* (edited by J. HÁLA, Budapest, 1987), *The Role of János Böckh and Hugó Böckh in the Hungarian Geology* (author: GY. VITÁLIS, Budapest, 1991), *Museums and Collections in the History of Mineralogy, Geology and Paleontology in Hungary* (edited by GY. VITÁLIS and T. KECSKEMÉTI, Budapest, 1991). From his scientific activity we have to mention the catalogue, which he compiled with MRS. I. DRAHOS and A. TARJÁN as co-authors, moreover his two studies on the journeys of ROBERT TOWNSON and EDWARD DANIEL CLARK in Hungary, presenting the geological and mining relations of them.

Scientific work cannot be done without books; well organized and properly functioning libraries are indispensable for it. The recent flood of information is mostly in English, whether we like it, or not. If we strive for the recognition of our scientific achievements by the world, we have to publish them in English — or at least in English as well. The work of the librarian and of the translator being however indispensable never gets a proper appreciation; being seldom spectacular it is always thankless. Often the selfish and impatient scholar notes just that a looked-for book is not available, or the translation needed urgently is not made according the time scheduled for it (by him of course...); that the translation finished at last follows the wording of the original text in excessively accurate mood —being thus "heavy handed"— or on the contrary it interpretes the author's thoughts too liberally becoming thus the transmutation rather than a translation of his writings.

ÁRPÁD KISS did his work in these fields, so to say in the shadow of Science. His translations were accepted by many foreign scientists with appreciation. We have good reason to say that Hungarian geology, the Geological Institute of Hungary and the Hungarian Geological Society all are greatly indebted to Him.

In the person of ÁRPÁD KISS we lost an experienced librarian and professional translator, a highly learned, always helpful and lovable man, colleague and friend. For the last farewell let us cite a verse of the poem "The Psalm of the Life" written by his beloved poet H. W. LONGFELLOW:

Life is real! Life is earnest!
And the grave is not its goal;
Dust thou art, to dust returnest,
Was not spoken of the soul.

Farewell!

KISS ÁRPÁD szakirodalmi munkássága — Scientific publications of ÁRPÁD KISS

Zastowanie telewizji przemislowej w Biblioteke Glównej Politechniki w Miskolc. — Társszerző: ZSÁMBOKI LÁSZLÓ. (With L. ZSÁMBOKI as co-author.) — Technológia Ksztecenia w Wyzszych Szkolach Technicznych 1972 (1): 85–89.

A Selmeci Műemlékkönyvtár kötetkatalógusa I. 1973. 149 p., II. 1974. 177 p. — Társszerző: DRAHOS ISTVÁNNÉ, TARJÁN ANDRÁS. (Translated title: Catalogue of the "Monument-Library" of Selmec [now Banská Štiavnica, Slovakia] in book form. With MRS. I. DRAHOS and A. TARJÁN as co-authors. — Miskolc.

Katalógushasználati szokások az NME Központi Könyvtárában. — Társszerző: UHLMANN ALADÁR. (Translated title: Customs of using the catalogue in the Central Library of the Technical University for Heavy Industry in Miskolc. With A. UHLMANN as co-author.) — Borsodi Könyvtáros 1973 12 (4): 14–17.

Angol utazóknak a magyarországi bányászattal, kohászattal és ásványvagyonkinccsel kapcsolatos megfigyelései a XIX. század második feléig. — Kézirat. (Translated title: Observations of English travellers concerning the mining, metallurgy and mineral resources of Hungary till the second half of the 19th century. — Manuscript.) — Miskolc, 1979.

Az Országos Földtani Szakkönyvtár tevékenysége. (Abstract: The Library of the Hungarian Geological Institute.) 1989. — Földt. Int. Évi Jel. 1987: 505–509.

ROBERT TOWNSON (1762–1822) angol utazó látogatása Magyarországon és bányászati–„geológiai" megfigyelései. (Abstract: ROBERT TOWNSON's (1762–1822) visit to Hungary and his mining–geological observations.) 1991 — Földt. Int. Évi Jel. 1988: 623–629.

Egy XIX. századi angol utazó geológiai–bányászati jellegű megfigyelései az alsó-magyarországi bányavárosokban. (Abstract: Geological–mining observations of a British traveller in the Lower Hungarian mining towns from the 19th century.) 1991 — Földt. Int. Évi Jel. 1989: 631–639.

ANN. REP. OF THE GEOLOGICAL INSTITUTE OF HUNGARY, 1992–1993/II: 9–14 (1999)

ON THE TECTONIC SUBDIVISIONS OF HUNGARY

by ZOLTÁN BALLA

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Manuscript received in 1993.

Keywords: structural geology, structural units, Hungary

UDC: 551.243(439) 551.248.1(439)

The structural geological map of Hungary (DANK, FÜLÖP 1990) is based on an outdated concept of the tectonic interpretation of structural units (see Table 1). It is also inconsistent (see Table 2) as the colouring of the map is more a geological than tectonical in character. We need a new kind of tectonic subdivision which divides Middle Cretaceous and younger formations into "elements", "units" and "super-units" (see Fig. 1). Older formations are divided into "domains" and "terrains". There are two "super-units" in Hungary. In the Middle Cretaceous they were separated by the Kapos–Tamási–Kulcs–Hernád Line; during the Senonian and the Paleogene this role was played by the Kapos Line and the Szolnok flysch belt.

Tectonic subdivision is a tool for analysing the structure of a given region. There are three aspects to consider, spatial, temporal and compositional. The relative weight attributed to these criteria and the hierarchy of classification depend on each author's views on tectonics and are decisive for the content and legend of the resulting tectonic maps.

Compilation of tectonic maps was for decades based on the geosyncline doctrine. By definition a geosyncline is a sedimentary basin that terminates with orogeny. In a wider sense, any tectonism can be derived from the prehistory of the area and regarded as a result of deep processes below the area. In the frame of that concept the age of a process or event is the main criterion for the tectonic subdivision, other aspects are subordinated.

In tectonic maps published 20–35 years ago for surrounding countries (SOKOŁOWSKI, ZNOSKO 1958, BIELY et al. 1968, DUMITRESCU, SĂNDULESCU 1970, MAHEĽ 1973), the coloring reflects first of all the age of the folding, in complete harmony with the above principle. Although temporal subdivision appeared in the hierarchy of the legends as third or fourth level relegated below the spatial subdivision, it governed the general impression from the maps.

In Hungary, the subdivision scheme (CSÁSZÁR, HAAS 1984), which served as a basis for "official" tectonic syntheses (e.g. BREZSNYÁNSZKY, HAAS 1985, FÜLÖP, DANK 1987, FÜLÖP et al. 1987, DANK, FÜLÖP 1990), was also used by numerous works not just papers on structural geology. This reinforces the need for a critical discussion of the tectonic subdivision of Hungary along with the analysis of the above scheme. Since during the decade of using that scheme neither its detailed description, nor its justification was published, we base its analysis on the content of its most detailed version (DANK, FÜLÖP 1990). In the further discussion we refer to it as the "Map".

The colours in the Map reflect the age of the sediment accumulation, not that of the folding. This is typical for geological maps. (For comparison: in tectonic maps of the surrounding countries "Triassic", "Jurassic" or "Cretaceous" colours mean Triassic, Jurassic or Cretaceous folding independent of the age of the accumulation). Therefore, we cannot regard the Map to be tectonic in concept. It is a simplified map of basement geology which includes some structural information.

In the Map, the depth contour lines "0" and "–4000" separate different colours. The depth indicated is the base of the Upper Badenian sediments, not the surface of the formations shown in colour. From the colouring of the Map and figures at the contour lines we could be misled to believe that the Upper Permian to Triassic sequences in the Danube Bend area north of Budapest lie above the sea level. Actually they are hundreds of meters, sometimes more than thousand meter below the sea level, under the Paleogene and Lower Miocene sediments which underlie Upper Badenian in that area. Consequently, "depth" colouring is misleading, and the value of the Map for basement geology is doubtful.

In the last 25 years plate tectonics had become the leading tectonic theory of the world. From its point of view, the classic orogeny is an *ensemble* of the phenomena during the collision between a continent and an island arc or more frequently between two continental plates

(DEWEY, BIRD 1970). The collision is caused by the plate movement, i.e. by factors outside of the basins, not by internal development of the basins which suffered the orogeny.

The change in the theoretical basis requires radical transformation of the attitude to the construction of tectonic maps and to their legend: coloring should primarily reflect the situation before the collision (orogeny), not age of the tectonic events. An example of a map of that type (although with no plate tectonic terminology) is the Tectonic Map of Italy (FUNICIELLO et al. 1981). Its colors show the original (Mesozoic) palaeogeographic position: a northwestern continental margin (plus the Penninic basin) and a southeastern continental margin (plus the Ligurian basin). Within them, the authors distinguished environmental types (e.g. systems of carbonate platforms and basins), then, tectonic zones (e.g. Piemont) and, only afterwards, the old basement and its sedimentary cover.

In the Map discussed, subdivision by age is dominating the legend. When the Map was published, in the 23rd year of the plate tectonics, this was already obsolete. The extension of the "Eo-Alpine" tectonic stage to the Permian through Early Cretaceous and of the "Pre-Alpine" tectonic stage to the pre-Cambrian through pre-Permian Paleozoic reflects an even more orthodox "geosynclinal" attitude than traditional tectonic maps in surrounding countries. For comparison: applying green color to the Permian to Lower Cretaceous sediments in the tectonic maps for surrounding countries means folding of the sequences in the Middle Cretaceous, it does not imply their accumulation in an "Eo-Alpine" stage). We can recognize a similar in the Explanatory Note to the International Tectonic Map of Europe (BOGDANOV et al. 1973, p. 70). We give some comparisons with a consequent plate tectonic subdivision (ZIEGLER 1982) in Table 1.

The Map realized spatial subdivision in a three-level hierarchy of "super-unit", "unit" and "sub-unit" (Table 2). There is only one (the Aggtelek–Rudabánya) sub-unit shown in the whole of the Map, so the reasons for the existence of this level are questionable. Relationships between the "Pre-Alpine" and "Eo-Alpine" Tisza and "Early to Middle Alpine" Szolnok super-units are not clear (for comparisons: the Pelso Super-Unit is present in all the three stages). It is difficult to see the reason for distinguishing the Szolnok Unit within the Szolnok Super-Unit which has no other units.

The Map gives no clear criteria for distinction between super-units and units. From a plate tectonic point of view, nappe systems containing both continental and oceanic sequences should constitute a distinct level in the hierarchy. Nevertheless, the "East Alpine" of them is designated as a "super-unit" whereas the "Gemer" and "Bükk" are simply "units". By these criteria, distinguishing between the two last "units" is groundless (GRILL et al. 1984). Originally, the Tethys Ocean has separated the "Eo-Alpine" Pelso and Tisza super-units, and this fact forces distinction between them on the highest level of the hierarchy. The East Alpine and Pelso super-units, however, were on the same side of the Tethys, therefore, from a plate tectonic point of view, distinction between them belongs to a lower level of the hierarchy. As a consequence, both the temporal, and the spatial subdivision in the Map are found untenable, so that we cannot use the Map for the tectonic subdivision of the country.

The tectonics of Hungary is not simple. At first glance we may think that in the Mesozoic and Cenozoic the Mid-Cretaceous orogeny was the only event to have affected any older sequences. But while the Permian–Mesozoic sequences of the Bükk–Aggtelek region suffered Cimmerian folding those in the Bakony region did not. Senonian and Paleogene are unfolded in the Bakony region. Senonian is folded at Nekézseny (Bükk–Aggtelek region) whereas the Paleogene is not folded all around it. Finally, both Senonian and Paleogene are folded in the Szolnok Zone. It seems that we need a scheme, flexible both in time and space, with the following components:

"Element" = a body with specific stratigraphy, composition, structural pattern etc., separated by tectonic boundaries from its surroundings. We can use this term with no limitation of magnitude.

"Unit" = an element or a group of elements set apart by basement structure. Outer boundaries may be sometimes active, but there were no significant displacements on the internal boundaries of the elements since the Mid-Cretaceous.

"Super-unit" = a unit or a group of units that had been separated for a rather long time period after the Mid-Cretaceous. Outer boundaries had been active for a period but there were no significant displacements on the internal boundaries of the units since the Mid-Cretaceous.

Any elements and units are components of the present-day structure whereas any of the super-units had only existed for a set period. Super-units are therefore defined in a palaeotectonic sense. Formally, any tectonic subdivision means grouping the elements into units/super-units and is only valid for a given time interval.

In Hungary, most of the tectonic boundaries that were active after the Mid-Cretaceous fall on steep lineaments (Fig. 1) whereas the most important tectonic boundaries for earlier periods fall on gentle dipping ophiolite zones. This fact is the reason to introduce a new category:

"Domain" = an element which originated either (1) from a continent and now bounded by an ophiolite zone or (2) from a basin with mafic crust now represented by an ophiolite zone. Present-day domains became separated tectonically from their surroundings after the closing of the mafic basins and the fusion of the continents on its margins, during the formation of the units or super-units.

In the Mid-Cretaceous and younger tectonics of Hungary, we distinguish the following units (Fig. 1): East Alpine, Vepor, Gemer (*sensu* GRECULA 1982), Bakony–Buda, Bükk–Aggtelek, Igal, Zemplén, Tolna, Szolnok (flysch zone) and Mecsek–Apuseni. The difference in shear structure separates the Igal Unit from the Bükk–Aggtelek Unit and the Tolna Unit from the Zemplén Unit (BALLA 1989).

Table 1 — 1. táblázat

Comparison of the temporal subdivision in DANK and FÜLÖP (1990) with that in ZIEGLER (1982)
A DANK és FÜLÖP (1990)-féle szerkezetfejlődési korbeosztás összevetése a ZIEGLER (1982) által alkalmazottal

Geological age Földtani kor	Stage of structural development in DANK and FÜLÖP (1990) Szerkezetfejlődési szakasz	Tectonic events in ZIEGLER (1982) Tektonikai események ZIEGLER (1982) szerint
Neogene Neogén	Neoalpine új-alpi	late orogenic collapse késő-orogén kollapszus
Oligocene oligocén		Alpine orogeny alpi orogenezis
Eocene eocén	Meso- középső	
Late Cretaceous késő-kréta	and és	onset of Alpine collision az alpi ütközés kezdete
Albian–Cenomanian albai–cenomán	Paleo-Alpine ó-alpi	rifting riftesedés
Early Cretaceous kora-kréta		
Late Jurassic késő-jura		polarization of rift systems riftrendszerek polarizációja
Middle Jurassic középső-jura		Mid-Cimmerian revolution középső-kimmériai revolúció
Early Jurassic kora-jura	Eo-Alpine eo-alpi	
Middle Triassic középső-triász		rifting riftesedés
Late Triassic késő-triász		
Early Triassic kora-triász		
Late Permian késő-perm		post-orogenic collapse posztorogén kollapszus
older idősebb	Pre-Alpine pre-alpi	Variscan orogeny variszkuszi orogenezis

From the **Senonian** to the **Paleogene** the main tectonic activity had been concentrated undoubtedly in the Szolnok Flysch Zone as shown by the complex facies pattern (SZEPESHÁZY 1973), foldnappe structure (BALLA 1982) and direct connection with the Carpathians towards the Maramureş–Magura zone (BALLA, BODROGI 1993). That is why we locate the first-order tectonic boundary for that time on the Szolnok Flysch Zone and its continuation, the Kapos Line. In Hungary, there is no other tectonic boundary of similar significance in that period. This is why we group all the units into two tectonic super-units. The Northwestern Super-Unit consists of the East Alpine, Vepor, Gemer, Bakony–Buda, Bükk–Aggtelek, Igal, Tolna and Zemplén units whereas the Southeastern Super-Unit only comprises the Mecsek–Apuseni Unit. We can regard the Szolnok Flysch Zone on their boundary either as a third super-unit or a nappe unit within the Southeastern Super-Unit thrust over the Mecsek–Apuseni Unit.

In the **Mid-Cretaceous** structure, the Szolnok Flysch Zone did not exist yet, and we locate the first-order tectonic boundary on the Kapos–Tamási–Kulcs–Hernád lineament. From the Senonian to the Paleogene we see a change. During this time the Tolna and Zemplén units belonged to the Northwestern, not to the Southeastern Super-Unit. Later changes, however, mean that the present-day distribution and configuration have not been inherited from that time. The Southeastern Super-Unit corresponds to the "Tisza Super-Unit" of the Map whereas the Northwestern Super-Unit, to the *ensemble* of both the "Pelso" and "East Alpine" super-units.

Table 2 — 2. táblázat

Principal tectonic data on super-units and units in DANK and FÜLÖP (1990)
A főegységek és egységek fontosabb tektonikai adatai DANK és FÜLÖP (1990) munkájában

Component Alkotóelem		Tectonic position Tektonikai helyzet		Age of the main orogeny A fő orogenezis kora
Super-unit Főegység	Unit Egység	At present Ma	Before the main orogeny A fő orogenezis előtt	
East Alpine Keletalpi	Upper Austroalpine Felső-keletalpi Lower Austroalpine Alsó-keletalpi Penninic Pennini	nappe takaró nappe takaró nappe? takaró?	African continental margin afrikai kontinensperem Ocean óceán	Middle Cretaceous középső-kréta and és Late Eocene késő-eocén
Pelso	Transdanubian Range[1] Dunántúli-khg-i Gömör[2] Bükk Mid-Transdanubia[3] Közép-Dunántúl	? nappe system takaróredszer nappe system takarórendszer nappe system takarórendszer	African continental margin afrikai kontinens-perem Ocean and two continental margins óceán és két kontinensperem	Middle Cretaceous középső-kréta Late Jurassic késő-jura and és Middle Cretaceous középső-kréta
Tisza	4	nappe system takarórendszer	European (?) continental margin európai (?) kontinens-perem	Middle Cretaceous középső-kréta and és Late Cretaceous[5] késő-kréta

1 "Bakony–Buda" in our terminology
2 "Aggtelek–Rudabánya" in our terminology
3 "Igal" in our terminology
4 Our "Mecsek–Apuseni", "Tolna" and "Zemplén" units are not separated
5 From data on the Apuseni Mountains in Romania

1–3 E tanulmány szerzőjének névhasználata szerint
4 Ezeket az egységeket az 1990-es mű nem választja szét
5 Bihar-hegységi (Románia) adatok szerint

In analysing the **pre-Mid-Cretaceous** structure, there is no sense in dividing the area into units and super-units. The fold–nappe structure of the units originated in Mid-Cretaceous orogeny, i.e. had been formed in a subsequent period. Nappes have been proven in the East Alpine and Bükk–Aggtelek units, and they are probable in the Vepor, Gemer, Igal, Tolna and Zemplén units. Their existence is disputed in the Bakony–Buda Unit. According to available data, the Vepor, Gemer, Tolna, Zemplén and Bakony–Buda units are all single domains whereas the East Alpine and Bükk–Aggtelek units consist of several domains: The East Alpine Unit includes the Penninic and Austroalpine domains, the Bükk–Aggtelek Unit the Bükk, Meliata and Aggtelek domains, respectively. We briefly discuss the problem of the domains/nappes of the Igal and Mecsek–Apuseni units below.

Upper Triassic carbonate rocks from borehole Igal–7 display low maturity of the organic matter (LACZÓ, JÁMBOR 1988). This is probably due to closer connection with the Aggtelek domain than with the Bükk domain and so this does not contradict correlation with the Bükk–Aggtelek Unit. We can regard the sporadic mafic and ultramafic rocks as well as the deep-water sediments of the Igal Unit to be analogs of the Meliata domain. The well-known marine Upper Paleozoic has analogs in the Bükk domain (para-autochtone). Consequently, we can

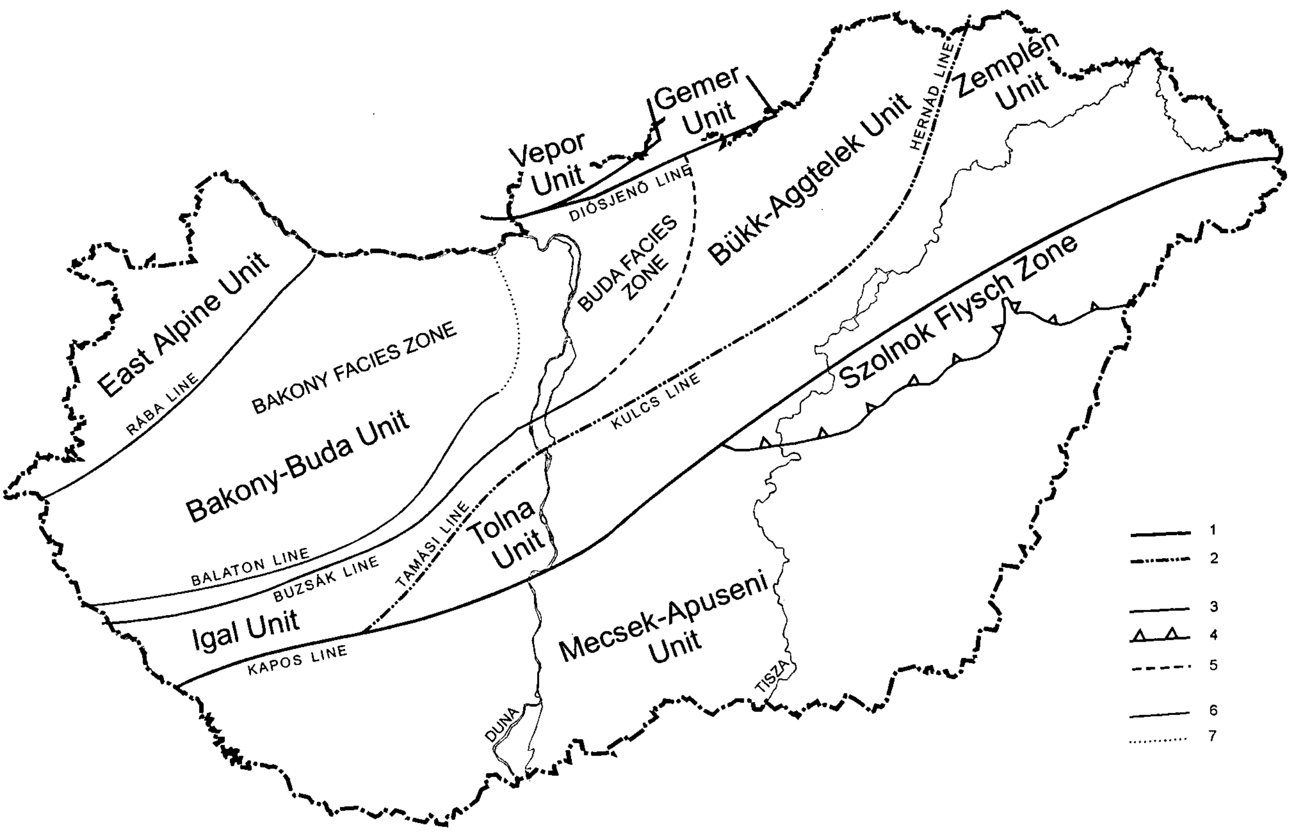

Fig. 1. Sketch of the tectonic subdivision of Hungary (Compiled by Z. Balla, 1992)
1–2. Super-unit boundaries: 1. Senonian to Cenozoic, 2. Middle Cretaceous; *3–5. Unit boundaries:* 3. Oligocene strike slip, 4. Oligocene thrust, 5. Boundary of uncertain age and type; *6–7. Facies zone boundaries:* 6. Oligocene strike slip, 7. Mesozoic facies boundary

1. ábra. Magyarország javasolt tektonikai felosztásának vázlata (szerkesztette: Balla Z. 1992)
1–2. Főegység határok: 1. Szenon–kainozoos, 2. Középső-kréta; *3–5. Egység-határok:* 3. Oligocén vízszintes eltolódás, 4. Oligocén feltolódás, 5. Bizonytalan korú és jellegű határ; *6–7. Fácies-zóna határok:* 6. Oligocén vízszintes eltolódás; 7. Mezozoos fácies-határ

recognize all the three domains of the Bükk–Aggtelek Unit in the Igal Unit, although, there is no possibility of spatial continuity.

In the Romanian part of the Mecsek–Apuseni Unit, a nappe pile with three principal components covers the Bihor Autochtone. Two of the components (Codru and Biharia) originated from a continental margin, the third (Mureş), from an ocean/island arc. In harmony with the above definition we only define here two domains: the Bihor+Codru+Biharia Domain being one of them, and the Mureş Domain is the other. Of course, one can further subdivide either of them, but the resulting elements will be of lower order of magnitude than domains ("terrains" etc.) as are the elements corresponding to the Lower and Upper Austroalpine nappes. As a consequence, we regard the Hungarian part of the Mecsek–Apuseni Unit, despite its nappe structure (Grow et al. 1989, Bardócz et al. 1991), as a single domain since there are no traces of the analogs of the Mureş Zone inside it. We do not take into account mafic volcanites in the basement of the Great Hungarian Plain due to their younger age and clear relationship with the Szolnok Flysch Zone (Balla 1982).

One can take the subdivision outlined above as a basis for constructing tectonic maps of Hungary.

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MAGYARORSZÁG TEKTONIKAI FELOSZTÁSÁRÓL

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ETO: 551.243(439) 551.248.1(439)

A Magyarország szerkezetföldtani térképén (DANK, FÜLÖP 1990) alkalmazott tektonikai felosztás elavult szemléletű (1. táblázat) és következetlen (2. táblázat), színezését tekintve pedig maga a térkép inkább földtani, mint tektonikai. Ezért új felosztási rendszerre van szükség, amelyben a középső-kréta és fiatalabb időszakban egyrészt a mai szerkezetet alkotó „elemek" és „egységek", másrészt az ezekből összeálló paleotektonikai értelmű „főegységek" (1. ábra), a középső-kréta előtti korszakokban pedig „domének" és „terrének" vannak. A „főegységek" határa a középső-krétában a Kapos–Tamási–Kulcs–Hernád-vonal, a szenon–paleogén folyamán pedig a Kapos-vonal és a Szolnoki-flisöv együttese.

LINEAMENTS OF HUNGARY

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Manuscript received in 1993.

Keywords: lineaments, Hungary

UDC: 551.243.8(439)

The structural pattern of the basement in Hungary is controlled by lineaments which are displayed on the Tectonic map of Hungary (Dank, Fülöp 1990). Some of the lineaments shown do not agree with the pattern deduced from geophysical data. The northern member of the Diósjenő pair of lines, the whole of the Buzsák line and the eastern continuation of the Kapos line are absent. A sketch of the lineaments compared with recent geophysical data is displayed on the Fig. 1 in the author's other article in this volume. The main lineaments are subdivided by the author into four groups on the basis of their structural role. Most of them are accompanied by dislocation zones.

It has been known for a long time that lineaments govern the structural pattern of the basement of the young basins in Hungary. The "official" Tectonic Map of Hungary, scale 1:500,000 (DANK, FÜLÖP 1990) displays them as "megatectonic" and "first-order tectonic" lines, and KÁZMÉR (1986) gives a good bibliographic review of them. In the following special attention is given to these lineaments of the official list (Fig. 1) and I will refer the map cited above as "Map".

The *Rába Line* is the boundary between the East Alpine and Bakony sequences in the basement of the Little Hungarian Plain (SCHEFFER 1962). Boreholes at Sótony and Ikervár help to define its position albeit with high uncertainty. The borehole Sót–1 penetrated Bakony type sequences, but the anchimetamorphic "diabase" in the neighbouring Sót–2 can either be of Bakony type (as at Litér, Velence etc.) or East Alpine type. The metamorphic sequences in the Ikervár boreholes farther to the West are of disputable position. JUHÁSZ and KŐHÁTI (1966) mentioned Upper Jurassic to Lower Cretaceous microfauna from the anchimetamorphites of Ike–2 whereas ÁRKAI and BALOGH (1989) gave 314 Ma K–Ar age for the anchimetamorphites of Ike–10. The first datum would result in "East Alpine", the second, in "Bakony" classification. There are certainly East Alpine sequences in the nearby borehole Pecöl Pe–1, and we regard the few km wide zone between the Sót–1 and Pe–1 as the dislocation zone of the Rába Line, with mixed sequences ("Nemeskolta Slate", BALLA 1993).

The position of the section #2 of the Rába Line (Fig. 1) depends on the classification of the Ikervár sequences, that of the section #1, additionally on the Alpine correlation. Magnetotelluric data trace the section #3 in the Northeast (HOBOT et al. 1987).

The *Diósjenő Line* forms the boundary between the Permian–Mesozoic sequences of the Bakony–Buda area and the "Vepor" crystalline (SZENTES 1961). Two subvertical planar magnetic bodies along the line (POSGAY 1967) mark dislocation zones filled by material unknown in neighbouring areas (BALLA et al. 1978, BALLA 1989a). The boreholes at Diósjenő, Szécsény and Sóshartyán found low-metamorphic sediments and mafic magmatites whereas garnet-bearing micaschists and gneisses are typical for the neighboring areas. Correlation with Slovak data revealed that both dislocation zones are continued towards the east as important structural boundaries (BALLA 1989b). The northern one becomes the boundary between the Vepor crystalline and Gemer Paleozoic, the southern forms the boundary between the Gemer Paleozoic and the Bakony–Buda Permian–Mesozoic complex.

The correlation with the Hurbanovo Line defines position of section #4 of the Diósjenő Line, and the geomagnetic anomaly pattern, that of section #5.

The *Balaton Line* forms the southern boundary of the shallow crystalline ridge along the southern shoreline of Lake Balaton (SZENTES 1961). In geological and seismic sections, the Balaton Line appears as a steep thrust with Carboniferous granites in the hanging wall. Below the thrust, in a 3–5 km wide zone, boreholes penetrated folded–imbricated Eocene, Oligocene and Lower Miocene sediments (BALLA et al. 1987) of "Buda" or "North Hungarian type" (BALÁZS et al. 1980). South of that zone, along the whole of Lake Balaton, a narrow basement high

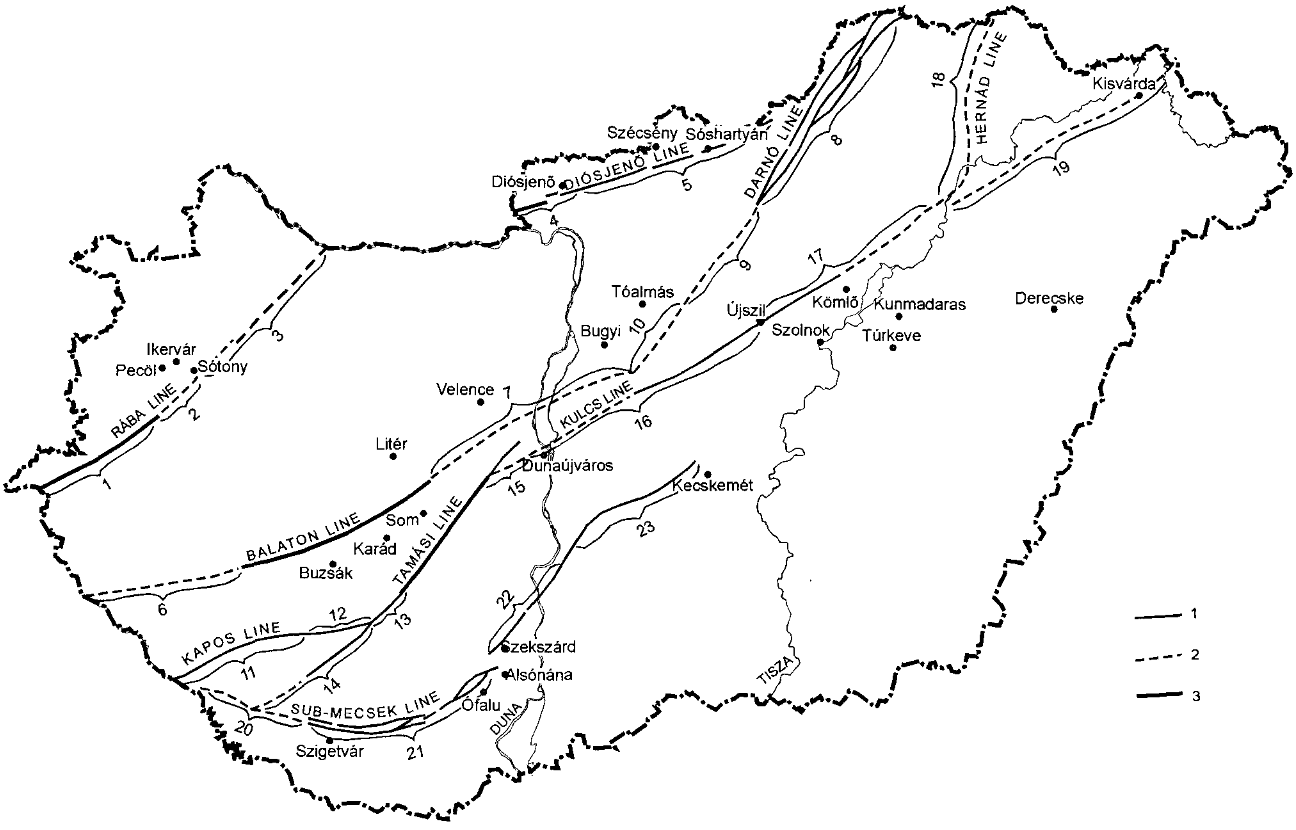

Fig. 1. Sketch of lineaments in DANK and FÜLÖP (1990)

1–2. Tectonic line in DANK and FÜLÖP (1990): 1. Continuous, 2. Dashed; 3. Acceptable position of a line. — Serial numbers indicate lineament sections discussed in the text

1. ábra. A szerkezeti fővonalak vázlata DANK és FÜLÖP (1990) térképén

1–2. Szerkezeti vonalak DANK és FÜLÖP (1990) szerint: 1. folyamatos, 2. szaggatott; 3. valamely vonal elfogadható helyzete. A számok a tárgyalt lineamentum szakaszokat jelzik

is traceable with Triassic sequences (Som, Karád, Buzsák, etc.) not correlatable with those of the Balaton Highland and Bakony Mts. These sequences are similar to those in the Bükk Mts. This is why most of the authors located the boundary between the Bakony and Bükk units at the Balaton Line (WEIN 1969, DANK, BODZAY 1971, BODZAY 1977, BALOGH 1983, DANK, FÜLÖP 1990).

In the last decade, however, it became clear that the "Bükk" type Permian is recognizable southwest of the Buda Hills (MAJOROS 1980) so that the area in question forms a transition between the "Bakony" and "Bükk" type Triassic (KOVÁCS 1980). Structural analysis revealed that the Velence granite body lies in the core of a pericline (DUDKO 1988, 1990) so that the sequences of the Buda area are traceable south of the granites and are also expected south of the Balaton Line.

Consequently, the Balaton Line, on one hand, is the boundary between the "Bakony" and "Buda", not "Bükk" facies areas, and on the other, it finishes NE of the Velence granites. The position of its western continuation (Fig. 1, section #6) depends on the Alpine correlation. The Map shows its eastern continuation (section #7) erroneously.

Due to the similarity of the "Buda" facies and the "Bükk" facies, lithology and stratigraphy are insufficient for defining the boundary between the Bakony–Buda and the Bükk structures. We can expect that boundary, on one hand, to lie south of the Balaton Line and, on the other hand, to be parallel to it. From the gravity anomaly pattern, we may assume the existence of a significant tectonic boundary between the basement high on the southern limb of the Balaton Line and the basement low south of it (BALLA et al. 1987). This is the *Buzsák Line* which is, however, absent from the Map.

In the West, the Buzsák Line probably merges with the Balaton Line, both being continued in the Pusteria (Gail Tal) Line, and the tectonic continuation of the Buda facies zone (BALLA 1989b) wedges out towards the west between them. From the gravity map, we may imagine the eastern continuation of the Buzsák Line both north and south of the Bugyi high, but the northern version makes better sense (BALLA 1989b).

The *Darnó Line* is a fault that bounds the Darnó Hill from the Northwest (TELEGDI ROTH 1937). Most of the authors (WEIN 1969 etc.) trace it into the fault on the NW rim of the Uppony Hills in the northeast. So, the Darnó Hill sequences are on the Bükk side of the Darnó Line, and both the geomagnetic anomaly pattern and drilling data on the magnetic sources (SZALAY et al. 1978) make a direct connection between the mafic sequences of the Szarvaskő and Darnó Hill fairly likely (BALLA 1989a). The steep position of the Lower Miocene beds in a borehole on the NW slope of the Darnó Hill and in mine galleries on the NW slope of the Uppony Hills point to a direct tectonic connection between these areas, and similar formations of the eastern rim of the Rudabánya Hills indicate further continuation (ZELENKA et al. 1983).

The Map displays four faults within the zone of the Darnó Line (Fig. 1, section #8). The NE continuation of the fault on the SE rim of the Darnó Hill crosses the uniform magnetic high between the Darnó Hill and Szarvaskő mafic magmatites at a low angle. Only by ignoring the geophysical and drilling evidence is it possible to correlate the Darnó Hill sequences with those in the Aggtelek–Rudabánya area, but even this does not allow correlation with the Bükk area. At Tóalmás, about 60 km SW of the Darnó Hill, a borehole penetrated Mesozoic mafic magmatites similar to those on the Darnó Hill (SZEPESHÁZY 1977). This served as a basis for tracing the Darnó Line in that direction (according to the traditional view, on the NW slope of the magnetic high), and the Map displays this situation (section #9). This, however, would mean that although the Tóalmás mafics of the Bükk Unit are not supposed to be correlated to those of the Darnó Hill as part of the "Gemer" Unit[1], they are nevertheless used to trace the Darnó Line. In other words, the Map abandons of the earlier concept of the Darnó Line in which the position of the Mesozoic mafic rocks, of the geomagnetic anomalies and of the steep Lower Miocene beds had a uniform structural explanation. Instead of this the Map offers a new alternative which does not explain some of the facts and in which the formerly established relationships disappear. No data support the SW continuation beyond Tóalmás (section #10). There is no basis for distinguishing between the "Bükk" and "Gemer" units (GRILL et al. 1984), thus, the Darnó Line does not play any significant role in the tectonic subdivision of Hungary.

WEIN (1968, 1969) located the eastern continuation of the *Zagreb Line* on the boundary between the "Kaposfő–Mágocs crystalline" and the "Bükk" type Upper Paleozoic and Mesozoic of the "Igal zone". The Map shows the Kapos Line, regarded as a young fault by NÉMEDI VARGA (1977), as a "protolineament" a few km south of that "megatectonic line". We think, however, that a wide dislocation zone within the basement represents the continuation of the Zagreb Line (WEIN 1969) and only one of its branches comes forward in the neotectonics (NÉMEDI Varga 1977). Consequently, we regard the Kapos Line to be continuation of the Zagreb Line.

Boreholes fix the position of the Kapos Line on its first 50 km in Hungary within a rather narrow strip (Fig. 1, section #11). Drilling data, however, do not define the next section (#12). We can locate both sections fairly well in the geomagnetic anomaly pattern. These sections cut across anomalies in the South which are connected with basement sources whereas the anomalies in the North, related to Miocene volcanites (POSGAY 1967), run parallel to the Line. That boundary can be traced to the Danube (BALLA 1989b), and we can follow the Line till the Kecskemét area in the anomaly pattern (where it approximately coincides with the section #23 in Fig. 1). We can similarly trace the Kapos Line in the gravity anomaly pattern. About 30 km east of the Danube, due to the increasing basement depths the picture becomes indistinct, and the further continuation of the Line is only visible in the geomagnetic anomaly pattern.

From the Kecskemét area there are two versions of tracing the line. We can imagine it either (1) to continue along the northern closure of geomagnetic anomalies with intrabasement sources (POSGAY 1967) towards Túrkeve and Derecske, and then, 10–15 km south of Debrecen or (2) to continue along geomagnetic anomalies towards Szolnok and Kunmadaras, and then, 10–20 km north of Debrecen. The continuation in the first version falls on the southern, in the second, on the northern boundary of the Szolnok Flysch Zone. This zone, in either of the versions, would indicate the structural continuation of the Kapos Line. Correlation with the Carpathians (BALLA, BODROGI 1993) makes the second version more probable. In its frame, we interpret the southern outline of the Flysch Zone as a nappe front.

The Map terminates the Kapos Line at a SW–NE directed fault. This is the *Tamási Line* that is clearly visible in the gravity anomaly pattern. Its SW continuation beyond the Kapos Line (Fig. 1, section #14) is a product of the conceptual map compiling. Drilling data are almost totally absent here, and therefore we consider this part of the section undefined. The position of the Tamási Line near the junction with the Kapos Line (section #13) is poorly defined by data. This allows us to assume an arch-like connection between them.

In the NE the Tamási Line dies out. Just before the termination of the line the *Kulcs Line* (name after WEIN 1969) approaches it from the East. The Map suggests 65 km of sinistral shift upon the Tamási Line. That shift, however, seems to be impossible to accomodate within the frame of the Map. At the same time, geophysical and drilling data allow us to arch the Tamási Line onto the Kulcs Line (Fig. 1, section #15).

On the northern flank of the Kulcs Line, near Bugyi and Kömlő numerous boreholes reached basement of "Bükk" type. South of the Line, however, the boreholes Dunaújváros Szt-1 (8 km from the Line) and Újszil-1 (70 km east of the Danube, 19 km from the Line) only reached the crystalline basement. Nevertheless, we can easily recognize the Kulcs Line east of the Danube for 80 km both in the geomagnetic and the residual gravity anomaly pattern (Fig. 1, section #16). Starting from Kömlő the continuation of the Kulcs Line in the Map gradually deviates from the linear geomagnetic high that served as the only tracing criterion. Since there are no drilling constraints we think it to be reasonable to deflect the Line gradually towards the North.

[1] Hungarian and some Slovak authors include Permian and Mesozoic south of the Rožňava Line into the Gemer Unit, this is the case here as well. The author accepts Grecula's view that "Gemericum" is restricted to the Paleozoic and regards the Permian and Mesozoic in question as the northern, Slovak part of the Aggtelek–Rudabánya sequences.

The Kulcs Line diverges towards the Northeast in the Map. *One of the branches* (section #18) turns to the North and runs zigzag in the basement of the NW part of the Tokaj Hills. Due to absence of boreholes this solution is not supported by data. Several kilometres to the west a fault is indicated by the rim of the Hernád Valley as well as by the geomagnetic and residual gravity anomaly pattern. This is the "*Hernád Line*" of Hungarian authors[2]. This branch has the same direction as the Kapos Line. It separates the Szendrő Paleozoic of the Bükk Unit from the Zemplén Paleozoic correlated with the Mecsek Paleozoic.

The second of the two branches (section #19) runs as the straight NE continuation of the Kulcs Line in an area where the basement is almost completely unknown. We cannot recognize this branch in the indistinct residual gravity anomaly pattern. At the same time it crosses the most pronounced basement-related geomagnetic anomaly of the area, the Kisvárda high, at the middle. Consequently, the existence of this branch is doubtful, and we regard the Hernád Line as the only continuation of the Kulcs Line.

The *Sub-Mecsek Line* forms the boundary between the Permian–Mesozoic sequences of the Mecsek Mts and the crystalline rocks. A 1–2 km wide zone of mylonites, tectonic breccias and imbrications follow it. In the zone of the Sub-Mecsek Line, the Map displays three faults west of Pécs, one fault east of Pécs and two faults north of the Mórágy granite (Fig. 1, section #21), none of them being "boundaries".

At Szigetvár in the West, Middle Cenomanian is known from one core sample (BODROGI 1989) and Paleogene is known from several. In WÉBER's (1985) map a narrow trough is probably marking the dislocation zone of the Sub-Mecsek Line. Further continuation towards the west (section #20) is awkward.

In the East, the Map shows the source of the linear Alsónána geomagnetic high as the continuation of the Ófalu schist zone. In spite of the location of the Sub-Mecsek Line on the Ófalu zone and bounding the Alsónána source zone by faults, the authors of the Map displaced the continuation of the Sub-Mecsek Line to coincide with the northern boundary of the Szekszárd granite. West of the Mecsek Mts, granites appear north of the Sub-Mecsek Line as well, thus, the limit of the distribution of granites is not a firm basis for tracing the Line. The proposed NE continuation (section #22) is therefore not acceptable. Instead, we favor following the the Alsónána magnetic source (BARABÁS et al. 1964).

Summarizing, we can conclude that the position of the lineaments in the Map only partially corresponds to present-day knowledge on them. The Map shows substantially correctly the Rába Line, the western section of the southern branch of the Diósjenő Line system, the central and western sections of the Balaton Line, some short sections (not indicated on Fig. 1) of the Darnó Line system, the middle section of the Tamási Line, and some sections (not indicated on Fig. 1) of the Kulcs Line and of the Sub-Mecsek Line. At the same time there are errors in displaying the eastern continuation of the Balaton and Sub-Mecsek lines, as well as the Hernád Line. The northern branch of the Diósjenő Line system, the whole of the Buzsák Line and the eastern continuation of the Kapos Line are absent in the Map. An up-to-date scheme of the lineament network is shown in Fig. 1 of another work (BALLA), in this volume.

We classify lineaments in Hungary as follows. *First-order lines* are the ones that separate areas with significantly different sequences (Kapos–Tamási–Kulcs–Hernád Line) or indicate zones of extra high mobility (Kapos–Szolnok Zone), i.e., separate tectonic super-units. *Second-order lines* are separating tectonic units of different tectonic history (Rába–Diósjenő and Buzsák lines). *Third-order lines* form the boundaries between areas of different facies types (Balaton Line). *Fourth-order lines* are well expressed in a structural sense but their role in the tectonic subdivision is doubtful (Darnó and Sub-Mecsek lines).

Dislocation zones follow lineaments. Borehole data provide evidence for them along the Balaton and Diósjenő lines. From correlation of geophysical and geological data, we assume to have dislocation zones along the Rába, Buzsák, Kapos, Tamási and Kulcs lines as well. These zones are several km wide so that one can display them at scales as small as 1:500,000. This should be taken into account in the compilation of maps in the future.

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[2] This is not the same as the "Hornad Fault" in the usage of Slovak authors.

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MAGYARORSZÁG LINEAMENSEI

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ETO: 551.243.8(439)

Magyarország medencealjzatának képét lineamensek határozzák meg. Ezeket elég részletesen ábrázolja Magyarország szerkezetföldtani térképe (DANK, FÜLÖP 1990). E vonalak egy része nem a geofizikai térképekkel összhangban van feltüntetve. A Diósjenői-vonalpár É-i tagja, a Buzsáki-vonal egésze és a Kapos-vonal K-i folytatása hiányzik. A fővonalak geofizikai ismeretekkel is egyeztetett szerkezeti lefutása a szerző e kötetben közölt másik cikkének 1. ábráján látható. A fővonalakat tektonikai szerepük alapján a szerző négy nagyságrendbe sorolja. Többségüket diszlokációs övek kísérik.

ANN. REP. OF THE GEOLOGICAL INSTITUTE OF HUNGARY, 1992–1993/II: 21–25 (1999)

BIOSTRATIGRAPHIC EVIDENCES OF THE TRIASSIC/JURASSIC BOUNDARY IN THE MESOZOIC HORST NEAR CSŐVÁR

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Manuscript received in 1993.

Keywords: biostratigraphy, fauna, Triassic, Liassic, horst, Csővár (NE-Hungary)

UDC: 56:551.76(234.373.33)

The author made a revision of some faunal localities so far neglected at Várhegy near the village of Csővár, Pest county. The study of the fossils proves the presence of the Rhaetian stage and the Liassic at Csővár.

The area of the Várhegy hill is situated near Csővár; the "Kődombok" (cairns) is opposite it towards the south. The abandoned quarry cut into the northern side of the latter, is considered as an abundant treasure trove of fossils. Fossil-rich strata are always problematic biostratigraphically, this is especially true of the Mesozoic horsts found near Csővár (Pest County).

In 1992, two faunal localities were subjected to revision. Although these localities were known for at least two decades, only a few fossils in a bad state of preservation had been collected from the site. So it was surprising that the last time these rocks were examined, they were found to contain fossils that required another revision of the stratigraphy of these much debated beds.

The first locality was found in rocks which outcrop at the NNW slopes of Várhegy in the form of small blocks of dolomitic limestone and calcareous dolomite containing the following bivalves:

Classis: Bivalvia LINNÉ, 1758 (BUONANNI, 1681)
Subclassis: Pteromorphia BEURLEN, 1944
Ordo: Arcoida STOLICZKA, 1871
Superfamilia: Arcacea LAMARCK, 1809
Familia: Parallelodontidae DALL, 1898
Genus: Parallelodon MEEK et WORTHEN, 1866

Parellelodon azzarolae (STOPPANI, 1861)
Plate I, 1–3

1861. *Arca Azzarolae* n. sp.; STOPPANI: p. 60, t. 7, f. 13–16
1964. *Parallelodon azzarolae* (STOPPANI); VÉGH: p. 35, Table III, Fig. 2, 3 and Table IV, Fig. 1

An internal cast in a good state of preservation, with the oblong contour characteristic of this species. In comparison to length and width the shell is thin. First find in the Triassic horsts situated on the left side of the Danube.

Subclassis: Heterodonta NEUMAYR, 1884
Ordo: Veneroida H. ADAMS et A. ADAMS, 1856
Superfamilia: Glossacea GRAY, 1847
Familia: Dicerocardiidae KUTASSY, 1934
Genus: Dicerocardium STOPPANI, 1865

Dicerocardium cf. *hungaricum* NOSZKY, 1939

1939. *Dicerocardium hungaricum* n. sp.; NOSZKY: p. 77–80, Table II, 1–5

An external mould resembling a short Dicerocardium with pointed-bicorn umbones. No closer identification was permitted by the bad state of preservation of this impression.

Both bivalves point to the Upper Triassic Rhaetian stage. Besides these, among various fragments and casts collected from the rocks of small isolated hills, there are some which could be classified into the group of Conchodus and Nucula.

Another noteable locality is a 2 to 3 metres thick zone of dolomitic limestone found on the steep southern slope of Várhegy, at a medium height. About 200 m long, it contains crinoidal ossicles and badly preserved brachiopods (mainly Rhynchonellids). One of them has been identified as

"*Rhynchonella*" sp. aff. *hungarica* BÖCKH, 1879
(Plate I, 6–7)

Within this zone, and even some metres beyond it, there are small, badly preserved colonial corals with of a size ranging from 1.5 to 3.0 mm. Their closer identification is hindered by the nature septae, badly preserved and rarely visible (Plate I, 8–9).

Stratigraphic remarks

The biofacies of the crinoidal-brachiopodal zone encountered on the southern slopes of Várhegy is completely unknown in the Norian to Rhaetian sequence of the Transdanubian Central Range, a rock succession into which can be fitted the Mesozoic horsts appearing on the east side of the Danube. However, the same biofacies is present in the Liassic succession of Hierlatz facies. Maybe the lithofacies of Csővár differs significantly from that of the Hierlatzkalk.

Recent studies suggest that there should be a biochronological hiatus between the Upper Norian (Sevatian) substages and the Liassic Hettangian stage (all of them classified stratigraphically upon evidence given by rich faunal associations, see Detre et al. 1988 and Kozur 1991, respectively). To our present knowledge, the Rhaetian bivalves we found may fill this hiatus. On the other hand, Rhynchonellids are likely to have been Liassic. The first record of the Liassic age was made by H. Kozur (in Kozur–Mock 1991) is based upon the conodont *Neohindeodella detrei* Kozur, the only Jurassic Conodonta species known. So these Rhynchonellids may represent a macrofauna confirming Kozur's classification (Fig. 1).

The Csővár horst, isolated on the east side of the Danube, represents a particular bio/lithofacial unit, thus the conclusions drawn from our paleontological-biostratigraphic study cannot be generalized for the horst region as a whole. Within this region, the presence of the Rhaetian stage and, especially, that of the Liassic has not yet been verified elsewhere.

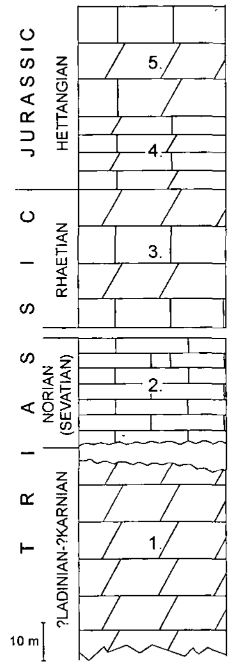

Fig. 1. Schematic stratigraphic column of the Mesozoic horst near Csővár

1. Unfossiliferous dolomite at Vashegy and in borehole Csővár Cs–1 (speculative correlation), 2. The big quarry at Csővár. Limestone with abundant fossils; chert-nodular, marly; *Choristoceras nobile* Mojsisovics, 3. The NNW slopes of Várhegy. Dolomitic limestone, calcareous dolomite, dolomite; chert-nodular; *Parallelodon azzarolae* (Stoppani), *Dicerocardium hungaricum* Noszky, 4. The Southern slope of Várhegy at a medium height: "*Rhynchonella*" sp., Crinoidal ossicles; ?Liassic. 5. The top part of Várhegy hill. Limestone, dolomitic limestone; chert-nodular; *Neohindeodella detrei* Kozur, radiolarians

1. ábra. A csővári mezozóos rög vázlatos rétegtani oszlopa

1. A Vashegy és a csővári (Cs-1/A) fúrás fosszíliamentes dolomitja (kettejük azonosítása hipotetikus), 2. A Csővári nagy kőfejtő. Faunadús mészkő; tűzkőgumós, márgás. *Choristoceras nobile* Mojsisovics, 3. A Várhegy ÉÉNy-i oldala. Dolomitos mészkő, meszes dolomit, dolomit; tűzkőgumós; *Paralellodon azzarolae* (Stoppani), *Dicerocardium hungaricum* Noszky, 4. A Várhegy D-i lejtője. Középmagasan: „*Rh.*" sp., crinoidea nyéltagok; liász?, 5. Mészkő, dolomitos mészkő, tűzkőlencsés, *Neohindeodella detrei* Kozur, Radiolariák

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A TRIÁSZ/JURA HATÁR BIOSZTRATIGRÁFIAI BIZONYÍTÉKAI A CSŐVÁRI MEZOZOOS RÖGBEN

DETRE CSABA

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Tárgyszavak: biosztratigráfia, fauna, mezozoikum, horszt, Csővár (Duna-balparti rögök)

ETO: 56: 551. 76(234. 373. 33)

Szerző a csővári Várhegyen található, eddig figyelmen kívül hagyott faunalelőhelyek reambulációjának eredményeit adja. Az ismertetett fauna bizonyítékul szolgál a felső-triász rhaeti emelet mellett, valamint alátámasztja a liász jelenlétét is.

A csővári Várhegy, valamint a tőle D-re szemközt lévő „Kődombok" — elsősorban az utóbbi É-i oldalában létesült egykori kőbánya — az ősmaradványok kimeríthetetlen tárháza. Mint minden ősmaradványokban gazdag rétegcsoport, a biosztratigráfiai problémák forrása. 1992-ben viszont két olyan ősmaradványlelőhely reambulációjára és kiértékelésére kerítettünk sort, amelyeket ugyan már legalább két évtizede ismertünk, de amelyekből mindeddig csak néhány nagyon rossz leletet tudtunk gyűjteni. Sikerült olyan ősmaradványokat gyűjteni, amelyek a sztratigráfiai besorolásokat illetően sokat hányatott rögcsoport rétegtani oszlopát megint átrendezik.

Az első lelőhelyről, a Várhegy ÉÉNy-i oldalán kibukkanó apró, dolomitos mészkő, meszes dolomit börcökből két kagyló érdemel említést:

Parallelodon azzarolae (I. tábla 1–3). Jó megtartású kőbél, jól kivehető a fajra jellemző téglalap alak és a hosszhoz és a szélességhez viszonyítva kis vastagság. A Duna-balparti triász rögökből új.

Dicerocardium cf. *hungaricum*. A jellegzetesen rövid, hegyes kétszarvú Dicerocardium-féleségnek két lenyomata maradt meg. A rossz megtartás miatt a faj biztos azonosítása nem lehetséges.

Mindkét kagylólelet a rhaeti emeletre utal. A börcökből előkerült anyagban ezeken kívül több töredék, ill. lenyomat között a Conchodus és Nucula kagylók alakkörét lehet fellelni.

A másik lelőhely a Várhegy D-i meredek oldalán középmagasságban kb. 200 m hosszan nyomon követhető, hozzávetőleg 2–3 m széles sáv, amelyben Crinoidea nyéltagok és rossz megtartású Brachiopodák, főleg Rhynchonellidák találhatók (I. tábla 4–5). Ezek közül meghatározható volt:

„Rhynchonella" sp. aff. *hungarica* (I. tábla 6–7).

Ezen a sávon belül, s néha több méterrel azon túl is apró, rossz megtartású telepes korallok találhatók, amelyek theca-átmérője mindössze 1,5–3 mm között mozog. Pontosabb meghatározásuk a nagyon ritkán és hiányosan látható septumok miatt lehetetlen (I. tábla 8–9).

Rétegtani megjegyzések:

A Várhegy D-i oldalán húzódó crinoideás-brachiopodás sáv biofáciese teljesen ismeretlen a Dunántúli-középhegység nori–rhaeti képződményeiből — amelynek együttesébe a Duna-balparti mezozoos rögök is besorolhatók —, viszont annál inkább jelen van a "hierlatz-fáciesű" liász képződményeiben. Meglehet, a csővári litofácies a Hierlatz Kalk-tól jelentősen különbözik.

A felső-nori (sevati) alemelet, amely gazdag faunával bizonyított (DETRE et al. 1988) és a szintén faunával bizonyított liász, hettangi emelet (KOZUR in KOZUR MOCK 1991) között a legutóbbi évek kutatási eredményei alapján biokronológiai hézag keletkezett. A rhaeti kagylók megtalálása ezt a hézagot — jelenlegi ismereteink alapján — kitölti. A nagy valószínűséggel liászba sorolható Rhynchonellidák pedig az eddig csak Conodonták alapján kimutatott liász (KOZUR 1991: Neohindeodella detrei, az egyetlen ismert jura Conodonta-faj) makropaleontológiai megerősítését jelenthetik (1. ábra).

A csővári rög a Duna-balparti rögökön belül különleges bio- és litofáciesű egység, így a rögök egészére ezek a fentiekben bemutatott őslénytani-biosztratigráfiai eredmények nem terjeszthetők ki. A rhaeti emeletre és különösen a liászra vonatkozólag — egyelőre — a rögökön belül máshol nem utal semmi.

Plate I — I. tábla

1–3. *Parallelodon azzarolae* (Stoppani), NNW slope of Várhegy — a Várhegy ÉÉNy-i oldala
4. Crinoidal ossicle — nyéltag
5. Section of a brachiopod (Rhynchonellid), Brachiopoda (Rhynchonellida) — metszet
6–7. "*Rhynchonella*" sp. aff. *hungarica* Böckh, (6. 3×, 7. 2×)
8–9. Sections of small coral thecae — apró korall theca-átmetszetek
4–9. S slope of Várhegy — a Várhegy D-i oldala

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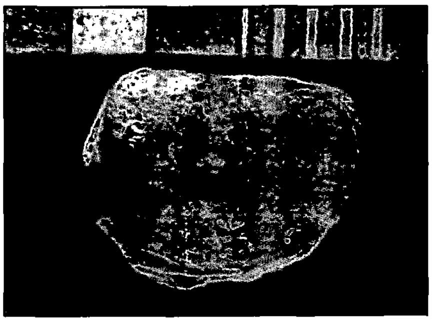

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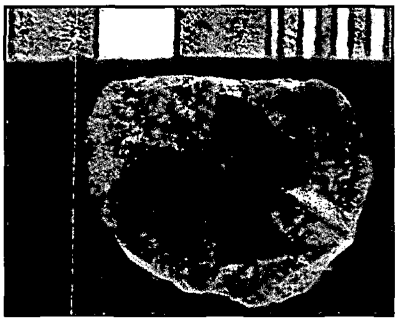

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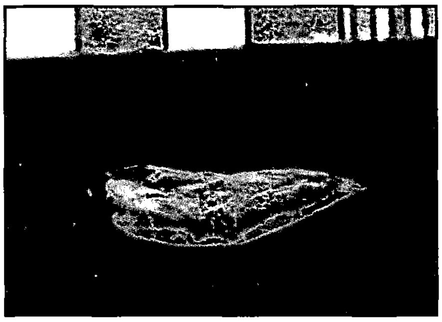

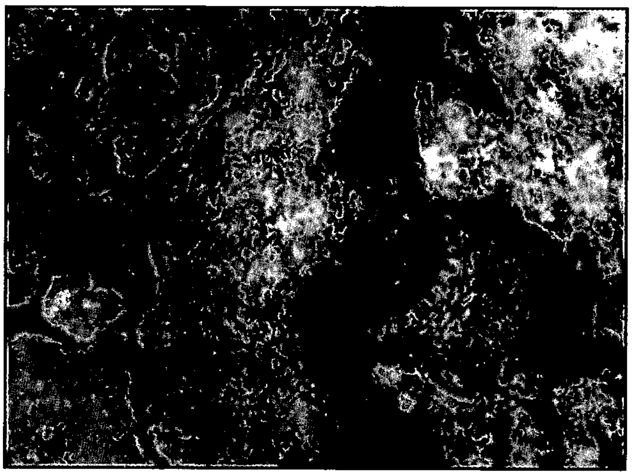

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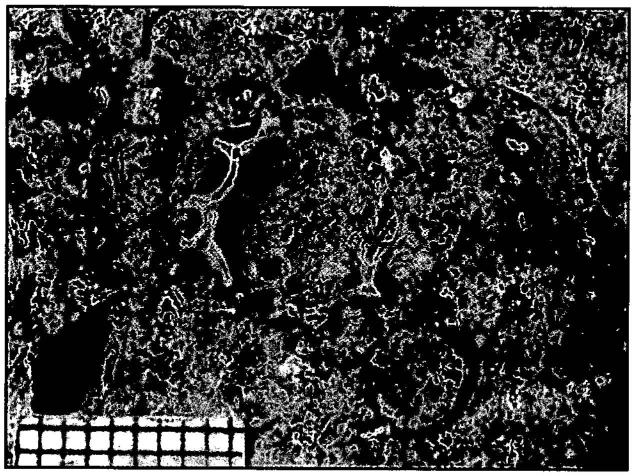

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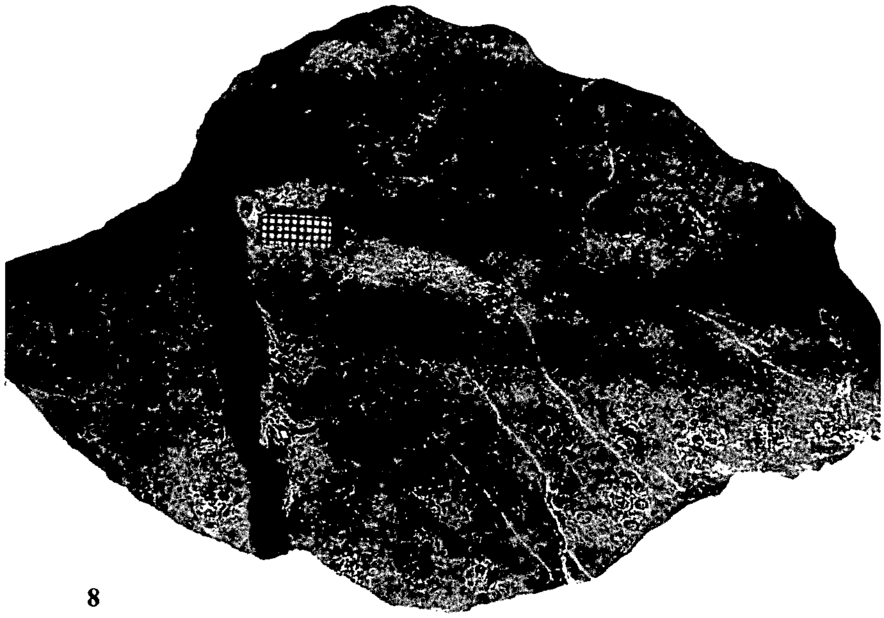

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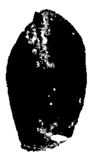

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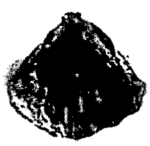

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ANN. REP. OF THE GEOLOGICAL INSTITUTE OF HUNGARY, 1992–1993/II: 27–52 (1999)

URGON LIMESTONE OF INVERSE POSITION IN THE SE FORELAND OF THE VILLÁNY MTS, TRANSDANUBIA, HUNGARY

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Manuscript received in 1993.

Keywords: Urgon, Nagyharsány Limestone Formation, SE Transdanubia, Lippó L–2 borehole, inverse position, Orbitolina, Sabaudia, Cretaceous

UDC: 551.763.13+551.763.3(234.373Villány Mts) 563.12(234.373Villány Mts)

As shown by Orbitolina investigation, borehole Lippó L–2 exposing the Nagyharsány Limestone Formation with a thickness of 1649 m indicates an inverse position and imbrication. The part of the sequence drilled with coring can be subdivided into 4 lithological subunits which refer to four extremely thick Orbitolina assemblage zones:

A) *Palorbitolina (E.) lenticularis–Palorbitolina (E.) charollaisi* Zone: 701.0 to 839.8 m. Lower boundary of the zone: unknown, while the upper boundary is at the first occurrence (FO) of the *Orbitolina (M.) parva* group. Accompanying species: *Dictyoconus barremianus*. The zone spans the Upper Barremian–Lower Aptian (Bedoulian).

B) *Orbitolina (M.) parva–Orbitolina (M.) texana* Zone: 839.8 to 1180.0 m. Lower boundary of the zone: FO of *Orbitolina (M.) parva* group, while the upper boundary: FO of *Simplorbitolina* gr. *manasi–S.* gr. *conulus*. Accompanying species: *Dictyoconus pachymarginalis*. The zone spans the Upper Aptian.

C) *Orbitolina (M.) texana–Orbitolina (M.) subconcava* Zone: 1180.0 to 1690.0 m. The lower boundary of the zone: FO of *Simplorbitolina* gr. *manasi–S.* gr. *conulus*, upper boundary: last occurrence (LO) of *Orbitolina (M.) parva*. Accompanying species: *Orbitolina (M.) pervia*. The zone spans the Upper Aptian–?Middle Albian.

D) *Orbitolina (M.) parva–Orbitolina (M.) texana–Sabaudia auruncensis* Zone: 1690.0 to 2000.0 m. This part of the sequence has been overthrusted on the Upper Aptian–?Middle Albian C zone. Both boundaries of the zone are unknown. Accompanying species: *Sabaudia minuta*, *S. capitata* and *S. briacensis*. The zone spans the Upper Aptian–Lower Albian.

In this sequence was identified for the first time in Hungary the species *Sabaudia auruncensis* (BODROGI 1987c). Data from PEYBERNES (1979), ARNAUD-VANNEAU and CHIOCCHINI (1985), SCHROEDER and NEUMANN (1985), MOULLADE et al. (1985) and VELIĆ (1988) have been used for the biozonation.

As concerns the "upper part" ranging 380.0 to 400.0 m only three thin sections are available which indicate bird's eye type tidal loferites and chara-bearing freshwater limestone and contain no age diagnostic taxa.

The calcareous algae include Dasycladaceae and Ethelia.

The extreme thickness of the sequence is an apparent one accordingly to the repetition of beds and the inverse faulting.

Introduction

A hydrological exploratory well drilled in the SE foreland of the Villány Mts to a depth of 2000.0 m exposed the Nagyharsány Limestone Formation in a thickness of 1649.0 m, overlain by 351 m thick Quaternary and Miocene (Pannonian) cover. A stratigraphic classification of the very thick Cretaceous shallow-water platform carbonate series was performed in the late 80's (BODROGI 1987c, 1991, 1994a). The results of the detailed and checked biostratigraphical study is done here. The discussion deals with other Nagyharsány Fm sections and with their age and footwall as well.

Geographical and geological basic data of the borehole Lippó L–2

The borehole in question was drilled in the area of Lippó village, at a distance of some 15 km S of Mohács (Fig.1). The coordinates (in HDR system) are:

$$x = -30{,}934.71;\ y = +36{,}626.84;\ z = 117.29.$$

The borehole was built up as a water well by the VIKUV (Water Prospecting Company) in the years 1980–1981, with hole bottom at 400.0 m, signed as Lippó, K. 2. The water was not used because of its chemistry. The drilling was continued in the years 1985–86 as a structure prospecting borehole by the MÉV (Mecsek Ore Mining Company), signed as L–2, and coring from 700 m downwards, with intermittent core sampling until 2000.0 m depth (MAGYAR 1981, TÉGLÁSSY 1989), where was stopped by the technical supervisor.

The borehole exposed the Lower and Middle Cretaceous Nagyharsány Limestone Formation betwen 351 to 2000 m, withouth reaching its underlying bed and supplying information thereon. The section was described by CSÁSZÁR in the range 701 to 1147 m, whereas by BODROGI in range 1147 to 2000 m. The samples are stored in a sample store of the Geological Institute of Hungary, at Pécs-Somogy.

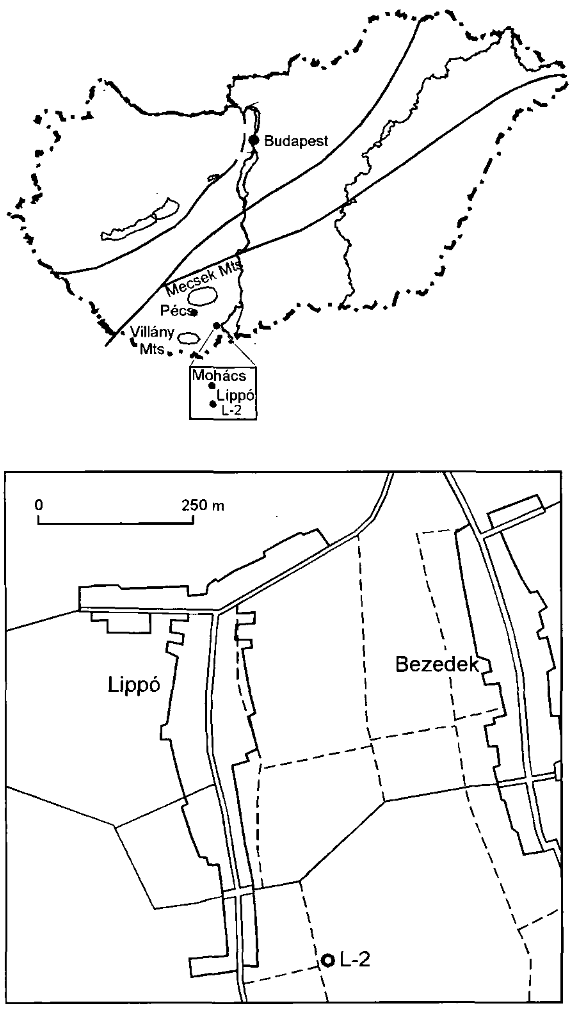


Fig. 1. The location of the borehole Lippó L–2
1. ábra. A Lippó L–2 fúrás helye

Nagyharsány Limestone Formation

Research history

In his monograph FÜLÖP (1966) has given a review on the research history. As for stratigraphy, he assigned the underlying Jurassic limestone to the Oxfordian–Lower Tithonian, the bauxite to the Valanginian/Hauterivian and the Urgon limestone to the Barremian–Lower Aptian. He distinguished four lithostratigraphic units. The small foraminifers, Orbitolinids and calcareous algae studies were performed by SIDÓ and MÉHES (in: FÜLÖP 1966). MÉHES (1966) described the new species *Orbitolina (M.) beremendensis* from Beremend.

PEYBERNES (1979) and PEYBERNES, CONRAD (1979) accepted the standpoint of FÜLÖP (1966) then I. NAGY (1988) confirmed the age of the underlying Szársomlyó Limestone. DUDICH and MINDSZENTY (1984) compared the petrographical and geochemical composition of the Harsányhegy Bauxite with those of the bauxites of the Pădurea Craiului Mts (Transylvania, Romania).

In the second half of the 1980's the renewed investigation of Urgon Limestone produced additional results. The limestone is subdivided by BODROGI (1987, 1988, 1989) and BODROGI et al. (1991a, b, 1992, 1993) into five litho–biostratigraphic units covering the Upper Berriasian/ Lower Valanginian to Middle Albian. It was formed in the course of an uplift taking place between the Earliest and the Late Berriasian. The Harsányhegy Bauxite was formed during the unroofing after the Early Berrriasian. Its source rock —according to HAAS (1984)— is assumed to have been the Mecsekjánosi Basalt Formation subjected to a rapid hemiautochtonous process. The upper, *Tubiphytes morronensis*-bearing member of the underlying Szársomlyó Limestone Formation (Várhegy Limestone Member, BODROGI 1993b) spans the Lower Berriasian beneath the bauxite lens VIII. The age of the oldest member of the Nagyharsány Limestone in its cover is Upper Berriasian/Lower Valanginian (BODROGI, KNAUER 1992). Similar relations have been found between the overlying and underlying beds in the profiles H (BODROGI et al. 1993, 1994), I and IA (BODROGI 1992) and NH (BODROGI 1993a, c). (The samples of the surface section H were collected by CSÁSZÁR, those of the sections I and IA by FEKETE and KNAUER while of the section NH by MINDSZENTY. Section H is the reference section of the surface stratotype section Nagyharsány–1).

In the borehole Nagykozár Nk–2 (located between the Mecsek and Villány facies belt) the Várhegy Member spans also the Lower Berriasian (BODROGI et al. 1994). The development of the Szársomlyó Limestone is likely to have continued even in the Early Berriasian. The Lower and Middle Cretaceous Nagyharsány Limestone Fm is a nappe and has been thrusted over the Mecsek Unit (BODROGI et al. 1994, BODROGI 1998).

CSÁSZÁR and FARKAS (1984) discovered shows of a second bauxite horizon in the Albian at Beremend. CSÁSZÁR (in: CSÁSZÁR et al. 1988, 1989) described reduced lofer cycles from the lower part of the transgressive sequence overlying the bauxite, distinguished after FÜLÖP (1966) four lithostratigraphic units, on the basis of the stratotype sequence Nagyharsány–1, that is the Nagyharsány quarry. CSÁSZÁR (1989), CSÁSZÁR et al. (1993) and CSÁSZÁR (in: CSÁSZÁR G. red. 1996) erroneously considered the lower part of the Nagyharsány Limestone Fm to be Hauterivian citing my first, unpublished, preliminary data from an internal report (BODROGI 1987/88).

The diploma and doctor's theses by S. NAGY (1987), ROTÁRNÉ-SZALKAI (1988), HORVÁTH (1990) also contributed to a better knowledge of the Nagyharsány and the Szársomlyó Fms. The first one deals with the stratigraphy and facies, the second one is devoted to the limestone types and bauxite geology, whereas the third one deals with the sedimentary and diagenetic processes (see also S. NAGY in: BODROGI et al. 1994).

In the NW–SW oriented range in the Villány facies belt a number of hydrogeological and petroleum exploratory boreholes exposed the Nagyharsány Limestone, the Szársomlyó Limestone and the Mecsekjánosi Basalt Formation which have also been described from the Danube–Tisza Interfluve, the middle part of the region beyond Tisza river and the SE foreland of the Villány Mts by CSÁSZÁR et al. (1983), BÉRCZI-MAKK (1986), BODROGI (1988a, b), ROTÁRNÉ-SZALKAI (1988) and PAP (1990).

New paleontological data on the formation aforesaid were presented at the 5[th] Calcareous Algae Symposium in 1991, Neaples and published in its proceedings (BODROGI et al. 1991a, b, 1993); at the Hungarian Geological Society (BODROGI, BÓNA 1988, BODROGI et al. 1996) and at the EUG VI[th] Meeting in Strasbourg, 1991 and later compared to the Schrattenkalk in Vorarlberg (Austria) and to its underlying beds (BODROGI et al. 1994).

SOKAČ (1996) revised taxonomically the calcareous algae of Barremian-Aptian age of the Adriatic region, extending it also to upper (but not the uppermost) part of the Nagyharsány Limestone Fm. He has confirmed our published data (BODROGI et al. 1993, 1994).

Geological setting

Occurrences of the Nagyharsány Limestone Fms belong to the Villány facies zone of the Mecsek–Apuseni Tectonic Unit (BALLA 1986, 1988), or Tisza-Microplate (CSONTOS 1995). Along the occurrences of the underlying Szársomlyó Limestone, Mecsekjánosi Basalt and Harsányhegy Bauxite Fms they are arranged into a range of NE–SW strike found at a depth of 1000 to 5500 m (boreholes Békés–2 and Mezőtúr–3) between the surface occurrence of the Villány Mts and Apuseni Mts (Transylvania, Romania). The Urgon sequence of the borehole L–2, examined in our study is in an inverse position, as shown by the Orbitolina–Sabaudia investigations.

Methodology

Methods: The study has been based on the investigation of Orbitolinid, smaller foraminiferal and calcareous alga assemblages in a total of 122 thin sections made from samples taken from the 700 to 2000 m interval.

Instruments: A Leitz Orthoplan microscope of the Geological Institute of Hungary was used.

Lithology

The Nagyharsány Limestone Fm is represented in the borehole Lippó L–2 from 351 to 2000 m, with an apparent thickness of 1649 m, by a very monotonous, unstratified, massive, grey, brownish grey, coffee-brown limestone sequence; strongly and slightly tectonised intervals alternate with tectonic breccia sections. The formation could be subdidivided into four subunits. The macroscopic differences in the 4 distinguished subunits are as follows:

Subunit 1. 701 to 838.8 m: Light grey, unstratified, massive limestone with aphaneritic texture and with Palorbitolina, belonging to the A (*Palorbitolina (E.) lenticularis–P. (E.) charollaisi*) Zone. The limestone has an apparent thickness of 138.8 m. It is of light grey, locally dark grey colour, sporadically with calcite spots. Very rarely stratification can be suspected dipping with 40–50°. Joints with 30–60° dip angles and gliding grooves also can be seen. Locally there are clay-film-bearing intervals with 65–75°dip.

Macrofauna: bivalves, small gastropods, both are sporadic. Microfauna: Calcareous- and arenaceous benthic foraminifers, on the wall of the cores Miliolid-rich and Miliolid-poor intervals are alternating. Orbitolinae are abundant at 839.1 m.

Subunit 2. Grey and brownish-grey, unstratified, clay-film-bearing limestone with aphaneritic and finecrystalline texture, with Mesorbitolinas. 839.6 to 1180 m it belongs to the B (*Orbitolina (M.) parva–O. (M.) texana*) Zone, with an apparent thickness of 340.4 m. Certain intervals of the limestone are densely clayfilm-bearing, somewhere with flaser structure (1063.8–1068.9 m; 1080–1098.2 m). Some intervals are strongly tectonised (840.4–848.1 m; 908–912 m). Tectonic breccia occurs at 843.2–843.6 m. The direction of the joints varies between 30–60°, 60–80° and 70–90° and they are filled mostly with red clay. The rock is in general intensely tectonised with the alternation of strongly and weakly tectonised sections. Dissolution and channels are common. Core recovery is poor.

Macrofauna: The quantity of rudists is varying rhythmically, but they are usually abundant. Toucasia is common in the 907–925 m interval, other bivalves and gastropods are sporadic. Microfauna: calcareous and arenaceous benthic foraminifers; Miliolids are common, while Orbitolinae are rare. Calcareous algae are sporadic.

Subunit 3. Brownish grey, coffee-brown unstratified limestone with aphaneritic texture and with calcite spots; Mesorbitolina-bearing from 1180 to 1690 m. Belonging to the C (*Orbitolina (M.) texana–O. (M.) subconcava*) Zone, it has an apparent thickness of 510 m. Slightly bitumenous, mostly strongly tectonised, with clay-film-bearing intervals; core recovery is poor.

Macrofauna: bivalves included toucasia, and other pachyodonts. Microfauna: calcareous- and arenaceous benthic foraminifers; Miliolids are abundant and Orbitolinidae are relatively rare. Calcareous algae: sporadically and not very well preserved.

Subunit 4. 1690 to 2000 m: Coffee-brown, greyish brown, unstratified, aphaneritic with calcite spots, Mesorbitolina- and *Sabaudia auruncensis*-bearing limestone. Belonging to the D (*Orbitolina (M.) parva–O. (M.) texana–Sabaudia auruncensis*) Zone, it has an apparent thickness of 310 m. This part of the borehole is overthrusted on the Upper Aptian–?Middle Albian sediments.

Slightly bitominous smell, varying strongly and less strongly tectonised intervals. Tectonic breccia occurs at 1930.1–1974.4 m.

Macrofauna: rudists (sporadic to fairly common, abundant in the interval 1808.2–1816.9 m), other bivalves. Microfauna: calcareous and arenaceous benthic foraminifers, Miliolids relative common, Orbitolina sporadical. Calcareous algae: the Dasycladaceae are rare and mostly fragmented.

Fossils in the Nagyharsány Limestone sequence

The macrofauna includes: bivalves including Toucasia and other pachyodonts, sporadically gastropods and brachiopods.

Components of the microfauna and mesofauna in thin sections are: foraminifers, echinoderms, bivalves, gastropods, sponges, hydrozoans, Spiroserpula, other Annelidae, corals. They are accompanied by calcareous algae: *Salpingoporella* cf. *melitae* RADOIČIĆ, *S. muehlbergi* (LORENZ), *S.* cf. *muehlbergi* (LORENZ), *Pycnoporidium lobatum* YABE et TOYOMA, *Ethelia alba* (PFENDER), *?Heteroporella* sp., *Vermiporella tennuipora* CONRAD, *Thaumatoporella parvovesiculifera* RAINER and encrusting algae. Incertae sedis: *Bacinella irregularis* RADOIČIĆ occurs in mass, apart from its minor fluctuations in the interval of 952 to 17l0 m, and indicates a caracteristically lagoonal facies. In addition it can be observed also at 1780 m, and is accompanied by *Pseudolithocodium carpathicum* MIŠÍK and *Lithocodium* sp. in the 1130 to 1160 and 1270 to 1780 m intervals.

State of preservation of the microfauna and microflora: good or medium, but the major part of Orbitolina are not very well preserved. The identification of the Orbitolina species was checked by A. ARNAUD-VANNEAU (Grenoble, head of IGCP 262 Team on Larger Foraminifers) and R. SCHROEDER (Frankfurt a/M.). Both in the Várhegy Member and in the Nagyharsány Limestone Formation the identification of the index fossils was checked also by other specialists as J. P. MASSE, B. SOKAČ and R. RADOIČIĆ. Part of the species was described by our coauthor M. A. CONRAD.

Data of ARNAUD-VANNEAU (1980, 1982, 1986), ARNAUD-VANNEAU and DARSAC (1984), ARNAUD-VANNEAU and CHIOCCHINI (1985), VELIĆ and SOKAČ (1978, 1983), VELIĆ et al. (1979), MOULLADE et al. (1985), SCHROEDER and NEUMANN (1985) and PEYBERNES (1979) have been used in the stratigraphic distribution of the index fossils.

Based on the occurrences of the Orbitolina species, it can be recognised that the sequence is in inverse position and not in a vertical one. The Upper Barremian–Lower Aptian species *Palorbitolina (E.) lenticularis* (BLUMENBACH) has been found abundant in the upper part (830.5 and 839.6 m) of the sequence (Fig. 2. and Plate I, 1 to 5); accompanying with *Palorbitolina (E.) charollaisi* SCHROEDER et CONRAD species also appearing in the Upper Barremian (839.0 m).

Orbitolina (M.) ex. gr. *parva* DOUGLAS first appearing at the base of the Gargasian is observed at 839.6 m (Plate III, 1 to 3), whereas *Orbitolina (M.) parva* DOUGLAS appears at 1040.0 m. *Orbitolina* ex. gr. *texana* ROEMER appearing in the upper part of the Gargasian, first appears at 1180.0 m. The FO of *Orbitolina (M.) subconcava* LEYMERIE was at 1020.0 m (det. SCHROEDER). Referring to upper part of the Gargasian. *Dictyoconus pachymarginalis* SCHROEDER (Plate IV, 5) was recognised at 1020.0 m. SCHROEDER described it first from the *Orbitolina texana*-bearing Gargasian from the Elburs Mts, Iran. The species *Orbitolina (M.) pervia* DOUGLAS that has a large geographic extent was first identified in Texas (Glen Rose Limestone). In the sequence of the borehole L–2 this species was observed together with *Orbitolina (M.) texana* and *O. (M.) subconcava*. VELIĆ (1988) assigned similar Orbitolina-bearing sequences in the Dinarides to the Lower Albian. *O.* (*M.) texana* was observed at 1180.0 m in the borehole. The genus Sabaudia is represented by four species, including the long-range *S. minuta* (HOFKER), *S. briacensis* ARNAUD-VANNEAU, *S. capitata* ARNAUD-VANNEAU and the short range species *S. auruncensis* (CHIOCCHINI et DI NAPOLI ALIATA) appearing in the Gargasian (ARNAUD-VANNEAU, CHIOCCHINI 1985) (see Plate I, 6 and Plate VI, 1 to 7).

The first occurrence of the last one was observed in this borehole at a depth of 1190.0 m (Plate I, 6).

A typical element of the Orbitolina fauna is represented by the *Simplorbitolina manasi–S. conulus* group which includes a great number of transitional forms. They appear in the Upper Aptian, and on the basis of data from BERTHOU and SCHROEDER (1978) typical *S. manasi–conulus* assocation have been observed in the Lower and Middle Albian, in the vicinity of Lisbon, Portugal. PEYBERNES (1979) indicated their occurrence in the Albian at Tenkes Hill. In the monograph by FÜLÖP (1966) *Simplorbitolina manasi* CIRY et RAT specimen is shown (p.105, Plate V, Fig. 4). In borehole L–2 this kind of type assemblage is observed in the interval of 1010.0 to 1019.5 m and can be followed to 1200.0 m (Plate IV, 3; Plate V, 2 to 6).

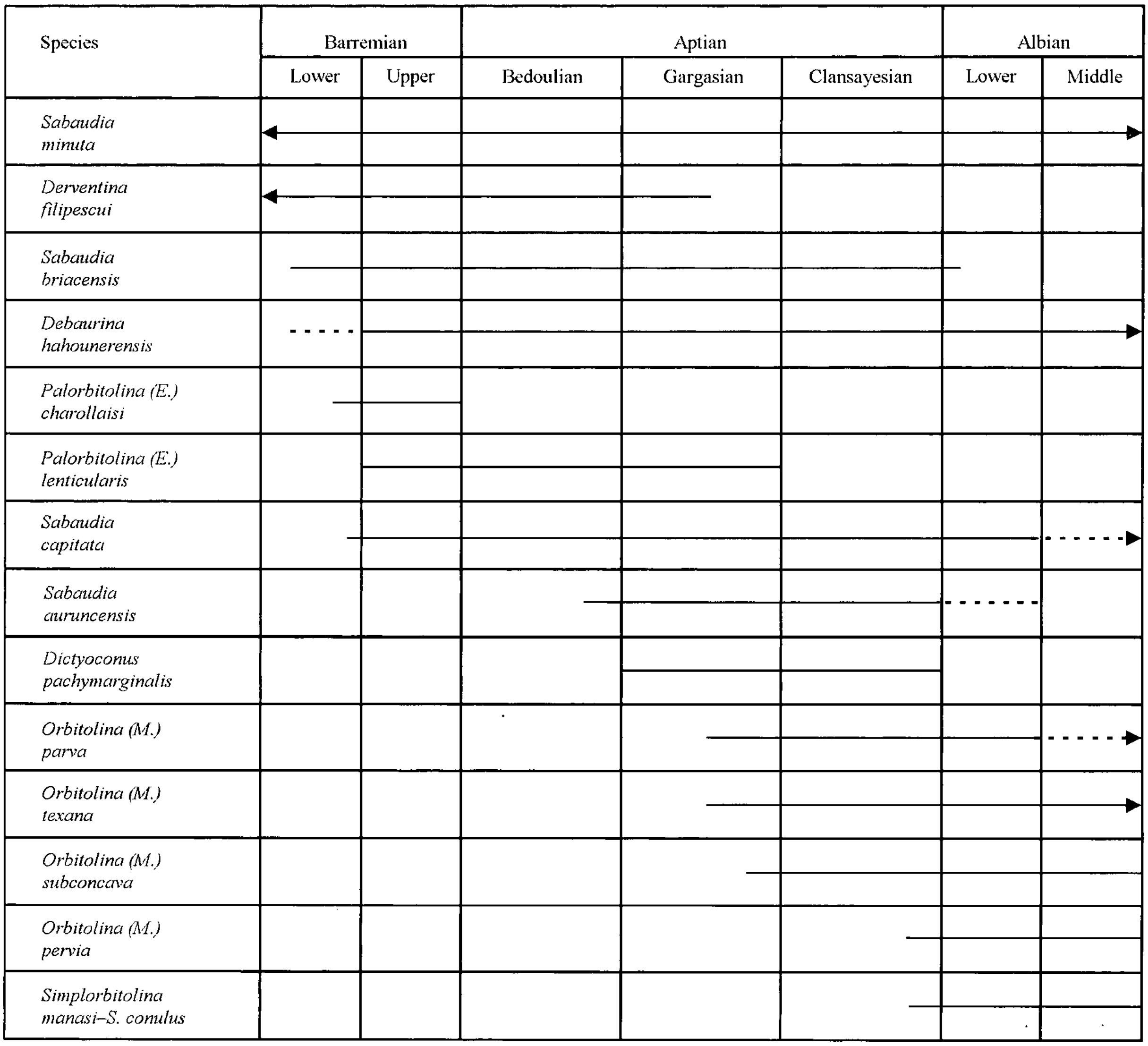
Orbitolina-stratigraphy and biozones

Due to facies related reasons, Orbitolinae forming the basis of the stratigraphic classification are not common in the sequence and are restricted to certain intervals. Their occurrence was observed even during the macroscopic description of the profile, therefore these intervals were more densely sampled.

As far as Orbitolina-based stratigraphy, is concerned, there are differences, for each in comparison to those index species, in the stratigraphic classification, validity and stratigraphic distribution given by MOULLADE et al. (1985), SCHROEDER and NEUMANN (1985), VELIĆ and SOKAČ (1983) and VELIĆ (1988). This also has an influence on the stratigraphic classification of the Urgon Nagyharsány Limestone Fm in the Villány Mts. These contradictions have been increased by the fact that species *Orbitolina (M.) minuta* DOUGLAS was described by MÉHES

Table 1 — 1. táblázat

Stratigraphic distribution of major foraminiferal species* — A fontosabb foraminifera fajok rétegtani elterjedése**



* According to the data of ARNAUD-VANNEAU and CHIOCCHINI (1985), MOULLADE et al. (1985), SCHROEDER and NEUMANN (1985), VELIĆ (1988) and the Team on Larger Foraminifera of IGCP 262.

** ARNAUD-VANNEAU és CHIOCCHINI (1985), MOULLADE et al. (1985), SCHROEDER és NEUMANN (1985), VELIĆ (1988) és az IGCP 262 nagyforaminifera csoportja (1992) adatainak felhasználásával.

(1964) as a new species referred to as *Orbitolina (M.) beremendensis* MÉHES.

PEYBERNES *(1979)* assigned *O. (M.) beremendensis* to the list of synonims of *O. (M.) minuta*. Later SCHROEDER (in: SCHROEDER, NEUMANN 1985) assigned *O. (M.) minuta* to the list of synonims of *O. (M.) texana* ROEMER, whereas MOULLADE et al. (1985*)* used *O. (M.) minuta* DOUGLAS as a valid one. *O. (M.) parva, O. (M.) minuta* and *O. (M.) texana* are included as independent species in a stratigraphic classification by VELIĆ and SOKAČ (1983), in which *O. (M.) minuta* is already omitted by VELIĆ (1988). Moreover, there is a disagrement concerning the status of *O. (M.) parva* DOUGLAS, since this species is still included in MOULLADE et al. (1985) and VELIĆ (1988) but neither of the listed valid species nor the list of synonyms are included in the atlas by SCHROEDER (in: SCHROEDER, NEUMANN 1985).

For classification and biozones of the Cretaceous sequence penetrated by borehole Lippó L–2, see Fig. 2.

Orbitolina and Sabaudia have provided the opportunity subdivide the Nagyharsány Limestone Fm into four assemblage zones including their zone markers:

A) *Palorbitolina (E.) lenticularis–Palorbitolina (E.) charollaisi* Assemblage Zone (701.0 to 839.8 m).

It has an apparent thickness of 138.8 m. The lower boundary of the zone is unknown. The upper boundary of the zone is at the apperence of *O. (M.)* ex. gr. *parva*. The 1st levels 830.5 and 839.8 m are relatively common for *Palorbitolina (Eopalorbitolina) lenticularis*, while at 839.8 m *P. (E.) lenticularis* and *Palorbitolina (E.) charollaisi* are abundant. *Paleodictyoconus barremianus* MOULLADE occurs at 839 m only.

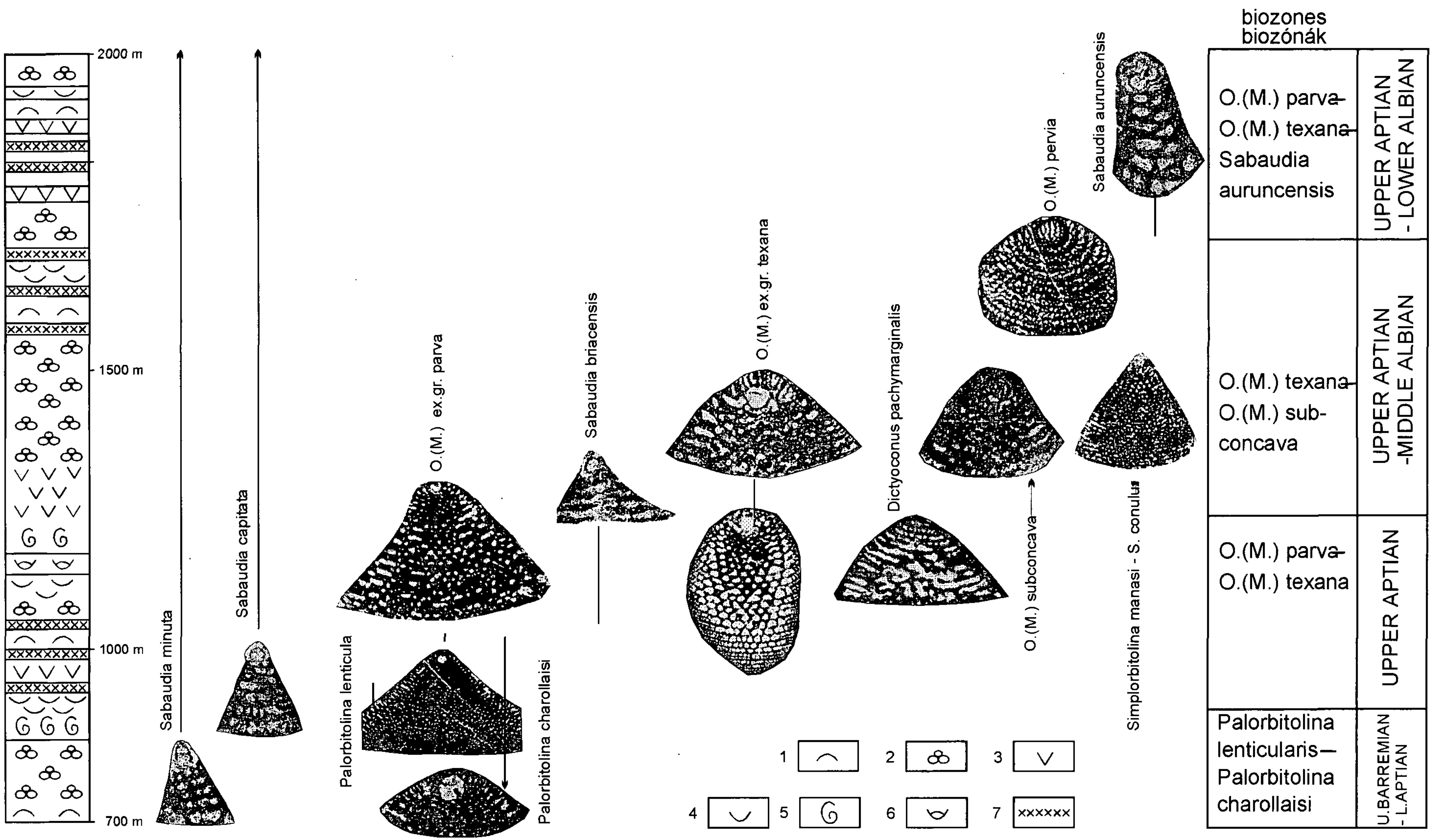


Fig. 2. Biostratigraphic classification of the inverse sequence of Urgon Limestone (Nagyharsány Limestone Formation) in the borehole Lippó L–2

1. Orbitolina, 2. Other forams, 3. Rudists, 4. Bivalves, 5. Gastropods, 6. Brachiopods, 7. Tectonic breccia

2. ábra. A Lippó L–2 fúrás átbuktatott urgon mészkő rétegsorának (Nagyharsányi Mészkő Formáció) biosztratigráfiai tagolása

Accompanying small benthic species include: *Arenobulimina* sp., *Debarina hahounerensis* FOURCADE, RAOULT et VILA, *Sabaudia capitata* ARNAUD-VANNEAU, *S. minuta* (HOFKER), *Charentia cuvillieri* NEUMANN, *Derventina filipescui* NEAGU, *Pfenderina globosa* FOURY, *Glomospirella urgoniana* ARNAUD-VANNEAU, *Myncina* aff. *termieri* HOTTINGER, *Novalesia* sp., *Textularia* sp., *Nezzazatinella macoveii* NEAGU, *Quinqueloculina robusta* NEAGU, *Bolivinopsis* sp., *Patellovalvulina* sp., *Pseudotriloculina* sp., *Pyrgo* sp., Miliolids (dominantly in medium size, common).

Accompanying calcareous algae (fragmented and sporadic): *Salpingoporella muehlbergi* (LORENZ), *S.* cf. *muehlbergi* (LORENZ), *S. melitae* RADOIČIĆ, *S.* sp., *Ethelia alba* (PFENDER) and *Thaumatoporella parvovesiculifera* (RAINERI).

The biozone spans the Upper Barremian-Lower Aptian (Bedoulian).

B) *Orbitolina (M.) parva–Orbitolina (M.) texana* Assemblage Zone (839.5 to 1180.0 m).

The biozone has an apparent thickness of 288.5 m. Its lower boundary is at the FO of *O. (M.)* gr. *parva*, whereas its upper boundary is assigned to the FO of *Simplorbitolina* gr. *manasi* CIRY and RAT–*S.* gr. *conulus* SCHROEDER. The zone marker species are accompanied by *Dictyoconus pachymarginalis* SCHROEDER and small benthic foraminifers: *Sabaudia minuta*, *S. capitata*, *S. briacensis* ARNAUD-VANNEAU, *Cuneolina pavonia parva* HENSON, *C.* sp., *Charentia cuvillieri*, *Debarina hahounerensis*, *Pfenderina* sp., *Glomospirella urgoniana*, *Nautiloculina cretacea* PEYBERNES, *Derventina filipescui*, *Textularia* sp., *Marssonella praeoxycona* MOULLADE, *M.* sp., *Reophax* sp., *Everticyclammina* sp., *Nezzazatinella macoveii*, *Trocholina aptiensis* IOCHEVA, small Miliolids (abundant), *Spirillina* sp., *Quinqueloculina robusta*.

Calcareous algae (sporadic and fragmented): *Salpingoporella muehlbergi*, *Ethelia alba*, ?*Cayeuxia* sp., *Boueiana* sp., *Thaumatoporella parvovesiculifera*.

Incertae sedis: *Bacinella irregularis* is common, *Pseudolithocodium carpathicum* occurred at 1400 m accompanied by *B. irregularis*.

The biozone spans the Upper Aptian.

C) *Orbitolina (M.) texana–Orbitolina (M.) subconcava* Assemblage Zone (1180.0 to 1690.0 m). The apparent thickness is 510.0 m.

The lower boundary is determined by FO of the *Simplorbitolina* gr. *manasi–S.* gr. *conulus*, whereas its upper boundary is at the last occurrence (LO) of *O. (M.) parva*.

Accompanying species: *Sabaudia capitata*, *S. minuta*, *S. briacensis*, *Simplorbitolina* gr. *manasi–S.* gr. *conulus* (at 1180 to 1200 m and at 1610 m), *O. (M.) parva and O. (M.) pervia* DOUGLAS.

Accompanying small benthic foraminiferal assemblage: in addition to the species listed for zones A and B, also *Textularia* div. sp., *Bolivina* div. sp., *Pseudocyclammina hedbergi* MAYNC, *Vercorsella arenata* ARNAUD-VANNEAU, *V.* sp., *Arenobulimina* sp., *Erlandia ?conradi* ARNAUD are included. Small Miliolids and Miliolids of medium size are abundant.

Calcareous algae (fragmented, sporadic): *Boueiana* sp., ?*Heteroporella* sp., *Salpingoporella* sp., *Ethelia alba.*

Incertae sedis: *Bacinella irregularis* is common.

The biozone spans the Upper Aptian–?Middle Albian.

D) *Orbitolina (M.) parva–Orbitolina (M.) texana–Sabaudia auruncensis* Assemblage Zone (1690.0 to 2000.0 m). The apparent thickness is 310 m.

This part of the sequence is overthrusted on the Upper Aptian–?Middle Albian sediments (C zone).

The zone is characterised by the dominance of species *Sabaudia minuta*, *S. capitata*, *S. briacensis*, *S. auruncensis* and *S.* aff. *auruncensis.*

Orbitolina (M.) gr. *parva* and *Orbitolina (M.)* gr. *texana* occurred only sporadically (1690.0 m, 1780.0 m, 1840.0 m and 1920.0 m). *Orbitolinopsis* sp. occurs at 1820 m. The fine material of their shells is merged into their enclosing rock, since in their habitat they used for building the micrite found in the infralitorale environment.

Agglutinated small benthic foraminifers: *Debarina hahounerensis*, *Arenobulimina meltae* KOVATSEVA, *Arenobulimina* sp. *Novalesia* sp., *Pfenderina globosa* sp., *Glomospirella urgoniana*, *Pseudolituonella* sp., *Textularia* sp., *Vercorsella* sp., *Gaudryina* sp.

Small calcareous benthic foraminifers: *Nezzazatinella macovei*, *Derventina filipescui*, *Bolivinopsis* aff. *capitata* YAKOVLEV, *Quinqueloculina robusta*, Miliolids (small and in medium size are relative common), *Pseudotriloculina* sp., *Pyrgo* sp.

Calcareous algae (sporadic and mostly fragmented, except *Salpingoporella muehlbergi*): *Ethelia alba*, *Pynoporidium lobatum* YABE et TOYOMA, *Salpingoporella* sp., *S. muehlbergi* (at 1470 to 1850 m frequent).

Incertae sedis: *Bacinella irregularis* (1690 to 1700 m, at 1780 m, 1800 m and 1890 m; common only at 1710 m).

The zone spans the Upper Aptian–Lower Albian.

Taxonomy

Genus: Sabaudia CHAROLLAIS et BRÖNNIMANN, 1965

Sabaudia auruncensis (CHIOCCHINI et DI NAPOLI ALLIATA, 1966)

Plate I, 6; Plate VI, 1–7

1966. *Textulariella auruncensis*; CHIOCCHINI et DI NAPOLI ALLIATA p. 6–8, 11; pl. 4, figs. 1, 2?, 3, 4?, 5– 7; pl. 5, figs.1?, 2?, 3–6, pl. 6, figs. 1–2; pl.; 7, figs. 1–2.
1970. *Sabaudia minuta*; FOURCADE p. 33; figs. 7, 8?
1973. *Sabaudia minuta*; FOURCADE et RAOULT pl. 2, fig. 6, 7?
1973. *Sabaudia minuta*; VELIĆ pl. IX, figs. 5, 7
1973. ?*Pseudotextulariella auruncensis*; VELIĆ pl. X, fig. 1
1975. *Sabaudia auruncensis*; GUŠIĆ pl. XXII, figs. 1–4, pl. XXIII, figs. 1–4, pl. XXIV, fig. 3–4
1977. *Sabaudia auruncensis*; VELIĆ pl. XXI, fig. 4, pl. XXIV, fig. 1, pl. XXVI, fig. 4, figs. 5–9
1977. *Sabaudia auruncensis*; CHIOCCINI et MAINCINELLI pl. 30, fig. 1
1978. *Sabaudia auruncensis*; GARCÍA-HERNANDEZ pl. 32, fig. 13, 14?

1978. *Sabaudia auruncensis*; ŠRIBAR pl. 8, fig. 3
1985. *Sabaudia auruncensis*; ARNAUD-VANNEAU et CHIOCCHINI pl. 2, figs. 1–9
1993. *Sabaudia auruncensis*; BODROGI et al. pl. 3, fig. 2.

Stratum: Nagyharsány Limestone Fm.

Locality: Borehole Lippó L–2 1690 to 2000 m.

Stage: Upper Aptian (Gargasian) to Lower Albian.

Description: Extremely elongated, arrow-formed, cylindrical, slightly pressed biserial; apical angle: 35–50°, the biserial stade consists of 4–12 chambers, adult specimens are dissected by radial walls of variable lenght, the proloculus is followed by three small postembrionale chambers.

Measurements:

length	0.330 to 0.616 mm
smallest diameter	0.330 to 0.345 mm
maximal diameter	0.370 to 0.410 mm
basale diameter of the juvenarium	0.106 to 0.133 mm
length of the juvenarium	0.065 to 0.100 mm
diameter of the proloculus	45 to 66 m.

Sedimentary environment: infralitorale with micritic sedimentation.

Stratigraphic and geographic distribution:

Italy: Upper Aptian (Gargasian) to basale? Lower Albian, Aurunci Mts, North Latium (CHIOCCHINI, DI NAPOLI ALLIATA 1966)

Spain: Upper Aptian (Gargasian), Caroch (FOURCADE 1970), Upper Aptian (Gargasian), Betiques Range (GARCÍA–HERNANDEZ 1978)

France: Upper Aptian (Gargasian), Aquitaine (ARNAUD-VANNEAU, unpublished)

Algerie: Upper Aptian (Gargasian), Constantinois, Kef Hahouner (FOURCADE et RAOULT, 1973

Croatia: Upper Aptian (Gargasian) to Lower Albian, Central Croatia (VELIĆ 1973, 1977, GUŠIĆ 1975)

Slovenia: Upper Albian (?), section Logarski planoti (ŠRIBAR 1979).

Conclusions and discussion

1. The structure exploration well Lippó L–2 has exposed the middle to upper part of the Nagyharsány Limestone Formation (Upper Barremian–?Middle Albian) in an extremely great apparent thickness of 1649 m.

2. Based on the assemblage of Orbitolinidae and smaller foraminifers, there is no doubt that the sequence becomes younger as heading downwards in the profile, in accordance with its inverse position. Considering the extremely great thickness of biozones, repetition of beds and overthrusting should also be recognised.

3. Four Orbitolina assemblage zones could be distinguished: A) *Palorbitolina (E.) lenticularis–P. (E.) charollaisi* (Upper Barremian-Lower Aptian); B) *Orbitolina (M.) parva–O. (M.) texana* (Upper Aptian); C) *Orbitolina (M.) texana–O. (M.) subconcava* (Lower Albian-?Middle Albian); D) *Orbitolina (M.) parva–O. (M.) texana-Sabaudia auruncensis* (Upper Aptian-Lower Albian). The D) zone is repeated with a characteristical Sabaudia facies, with *S. auruncensis* and shifted over zone C.

4. In assemblage zone C *Simplorbitolina* gr. *manasi–S.* gr. *conulus* occur.

5. In borehole Lippó L–2 was the first found of *Sabaudia auruncensis* (CHIOCCHINI et DI NAPOLI ALIATA) species in Hungary (BODROGI 1987c, BODROGI et al 1993).

6. Neither *Orbitolinopsis capuensis* (DE CASTRO) nor *Salpingoporella dinarica* RADOIČIĆ have been found in the samples of the L–2 sequence. The absence of *Salpingoporella dinarica* RADOIČIĆ has led us to the conclusion that there was no connection with the Adriatic platform during the Aptian (BODROGI et al. 1993). The same holds true for the Pădurea Craiului region (Apuseni Mts) in Romania (BUCUR 1981).

7. The borehole has not penetrated the boundaries of the formation. Therefore data concerning the lower part of the formation and the underlying Szársomlyó Limestone Fm can be obtained only from other sources such as the stratotype area of the two formations, the key sections: the Nagyharsány–1 stratotype section, the borehole Nagyharsány–1 and the bauxite exploration sections of Harsány-hegy (hill) at Nagyharsány.

8. According to J. FÜLÖP (1966) and I. NAGY (1988) the main body of the Szársomlyó Limestone is of Oxfordian–Early Tithonian age. Its uppermost, shallow water part (Várhegy Member, BODROGI 1993, 1998), which is the footwall of the Harsányhegy Bauxite Fm, proved to be Upper Tithonian–Lower Berriasian by its *Tubiphytes morronensis* facies and index fossils *Clypeina jurassica* FAVRE, *Suppilulimaella* sp., *Protopeneroplis trochangulata* SEPTFONTAINE, *Rectocyclammina* cf. *chuberti* HOTTINGER and *Globospirillina neocomiana* MOULLADE (according to the bauxite exploration sections H, I, IA, NH and borehole Nagykozár Nk–2 (BODROGI 1989, 1993a–c, BODROGI et al. 1991a, b, 1994, BODROGI, KNAUER 1992, BODROGI 1993a–c). There is no *Protopeneroplis striata* WEYNSCHENK in the Várhegy Member profile studied.

9. Considering the first marine interbeds with calcareous algae, the lower part of the Nagyharsány Limestone Fm (immediate cover of the Harsányhegy Bauxite Fm) deposited during the latest Berriasian–Early Valanginian, according to the species *Clypeina marteli* EMBERGER, *C.? solkani* CONRAD et RADOIČIĆ, *Salpingoporella katzeri* CONRAD et RADOIČIĆ and *Protopeneroplis trochangulata* SEPTFONTAINE (BODROGI 1989, 1993a, BODROGI et al. 1991a, b, 1993, 1994, BODROGI, KNAUER 1992). Associated species is *Salpingoporella annulata* CAROZZI. There is no *Protopeneroplis banatica* BUCUR in the lower part (= I. litho-biostratigraphic unit, I.b subunit) of the section Nagyharsány–1 (BODROGI et al. 1994, fig. 4.).

10. The *Protopeneroplis trochangulata* Taxon Range Zone (SEPTFONTAINE 1974) has been extended to the whole Berriasian (after GRADSTEIN et al. 1994: 7.2 Ma). In our case it spans the Várhegy Member of the Szársomlyó

Limestone Fm, the Harsányhegy Bauxite Fm and the litho-biopstratigraphic unit I. of the Nagyharsány Limestone Fm.

11. The *Protopeneroplis trochangulata–Clypeina jurassica* event (= last occurrence of the both species) (BODROGI 1993) which marks uplift elevation in the Villány facies zone, has produced the Várhegy Member.

12. The assemblage of foraminifers and calcareous algae in the lower part of the Nagyharsány Limestone Fm (Upper Berriasian–Lower Hauterivian) in the stratotype section Nagyharsány–1 matches that of the Adriatic platform. They belong to the same paleobiogeographic province (BODROGI et al. 1993).

13. The lower part of the Nagyharsány Limestone Fm has erroneously been considered to be Upper Hauterivian citing my first, unpublished, preliminary data from an internal report of the Geological Institute of Hungary (BODROGI 1987, CSÁSZÁR 1996, CSÁSZÁR et al. 1993). During the further studies of the formation many additional data were described and published. It would be desirable to correct this erroneous citation, according to the documents presented here.

14. The biostratigraphic results of the investigation of the Lippó L–2 sequence (BODROGI 1987c) were used by the OTKA (National Scientific Research Fund) research team (SZEDERKÉNYI et al. 1990) for the maturity test of organic matter in their work on the Villány facies zone.

Acknowledgements

I express my due thanks to A. ARNAUD-VANNEAU (Grenoble), R. SCHROEDER (Frankfurt) and M. A. CONRAD (Geneva) for checking the Orbitolina-based and calcareous algae, to H. LOBITZER (Vienna) for the help in this topic at the IGCP 262 meeting in Vienna in 1988, to H. KOLLMANN (Vienna) for the support at the same session, to VELIĆ and B. SOKAČ (Zagreb) for the quick professional help, to I. BUCUR (Cluj) for his co-operation, to I. VICZIAN for the help in translation, to E. DUDICH for the very accurate linguistic review and to J. KNAUER for his assistance in the editing of the present paper.

(Explanation of the plates)

All the photos represent the sequence of the Nagyharsány Limestone Formation (Upper Barremian-?–Middle Albian) penetrated by the borehole Lippó L–2.

Photo: the Author and Ms Pellérdy.

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INVERZ HELYZETŰ URGON MÉSZKŐ A VILLÁNYI-HEGYSÉG ELŐTERÉBŐL

BODROGI ILONA

Magyar Állami Földtani Intézet, 1143 Budapest, Stefánia út 14.

Tárgyszavak: Urgon, Nagyharsányi Mészkő Formáció, DK Dunántúl, Lippó L–2 sz. fúrás, átbuktatott helyzet, Orbitolina, Sabaudia, kréta

ETO: 551.763.13+551.763.3(234.373Villány Mts) 563.12(234.373Villány Mts)

A Lippó L–2 fúrás 1649 m vastag pannonfedős urgon mészkő (Nagyharsányi Mészkő F.) rétegsorából az alsó, 701–2000 m közti szakasz túlnyomó része magfúrással mélyült. A 122 db vékonycsiszolat Orbitolina és kisforaminifera vizsgálata révén megállapítható volt, hogy a rétegsor az *Orbitolina, Sabaudia* és kisforaminifera társulások fiatalodási trendje szerint átbuktatott helyzetben van és 1690 m-nél egy nagyobb feltolódás mutatható ki. A makroszkóposan rendkívül egyveretű, szürke és kávébarna közti színárnyalatú, afanerites és finom kristályos szövetű, rétegzetlen, tömeges mészkő, szakaszonként változó mértékben, erősen tektonizált, 2–10 cm-es darabokra esik szét, oldási üregek és meredek dőlésű vízjáratok tagolják. Makrofaunáját főként rudisták (Toucasia) képviselik, viszonylag ritka az egyéb kagyló és csiga. Helyenként szabad szemmel is jól láthatók az Orbitolinák és a nagy tömegben jelen lévő Miliolinák.

A rétegsor 4 rendkívül vastag *Orbitolina* együttes zónára tagolható, melyek közül a most legalul elhelyezkedő D zóna az átbuktatás előtt rátolódott a C zónára.

A) 701,0–839,6 m-ig: *Palorbitolina (E.) lenticularis–Palorbitolina (E.) charollaisi* Zóna. Látszólagos vastagsága: 138,0 m. A zóna alsó határa ismeretlen, felső határát az *Orbitolina (M.) parva* csoport belépése jelöli ki. Kísérőfaj: *Dictyoconus barremianus* MOULLADE. Rétegtani terjedelme: felső-barrémi–alsó-apti (bedouli).

B) 839,6–1180,0 m-ig: *Orbitolina (M.) parva–Orbitolina (M.) texana* Zóna. Látszólagos vastagsága: 340,4 m. Kísérő faj: *Dictyoconus pachymarginalis* SCHROEDER. A zóna alsó határa: az *Orbitolina (M.) parva* csoport belépése. A zóna felső határa: a *Simporbitolina* gr. *manasi* CIRY et RAT–*Simplorbitolina* gr. *conulus* SCHROEDER csoport belépése. Rétegtani terjedelme: felső-apti.

C) 1180,0–1690,0 m-ig: *Orbitolina (M.) texana–Orbitolina (M.) subconcava* Zóna. Látszólagos vastagsága 510,0 m. Alsó határa: az *Orbitolina (M.) texana* csoport belépése, felső határa: az *Orbitolina (M.) parva* kilépése. Kísérő fajok: *Orbitolina (M.) pervia, Orbitolina (M.) parva, Simplorbitolina* gr. *manasi–S.* gr. *conulus* SCHROEDER. Rétegtani terjedelme: Felső-apti (gargasi)–?középső-albai.

D) 1690,0–2000, m-ig: *Orbitolina (M.) parva–Orbitolina (M.) texana–Sabaudia auruncensis* Zóna. Látszólagos vastagsága 310,0 m. Mind az alsó, mind a felső zónahatár ismeretlen. Ez a köteg (D zóna) rá van tolva a C zónára és egy jellegzetes, tartósan fennálló sabaudiás hátteri lagúna fáciest képvisel. Kísérő fajok: *S. minuta* (HOFKER), *S. capitata* ARNAUD-VANNEAU és *Sabaudia bricensis* ARNAUD-VANNEAU. A zóna rétegtani terjedelme: felső-apti–alsó-albai.

Ebben a fúrásban határozták meg hazánkban először a *Sabaudia auruncensis* (CHIOCCHINI et DI NAPOLI ALLIATA) fajt.

Az igen nagy vastagságú rétegsor rétegismétlődésekkel, feltolódással tagolt. 380,0–400,0 m-ből csupán 3 db vékonycsiszolat áll

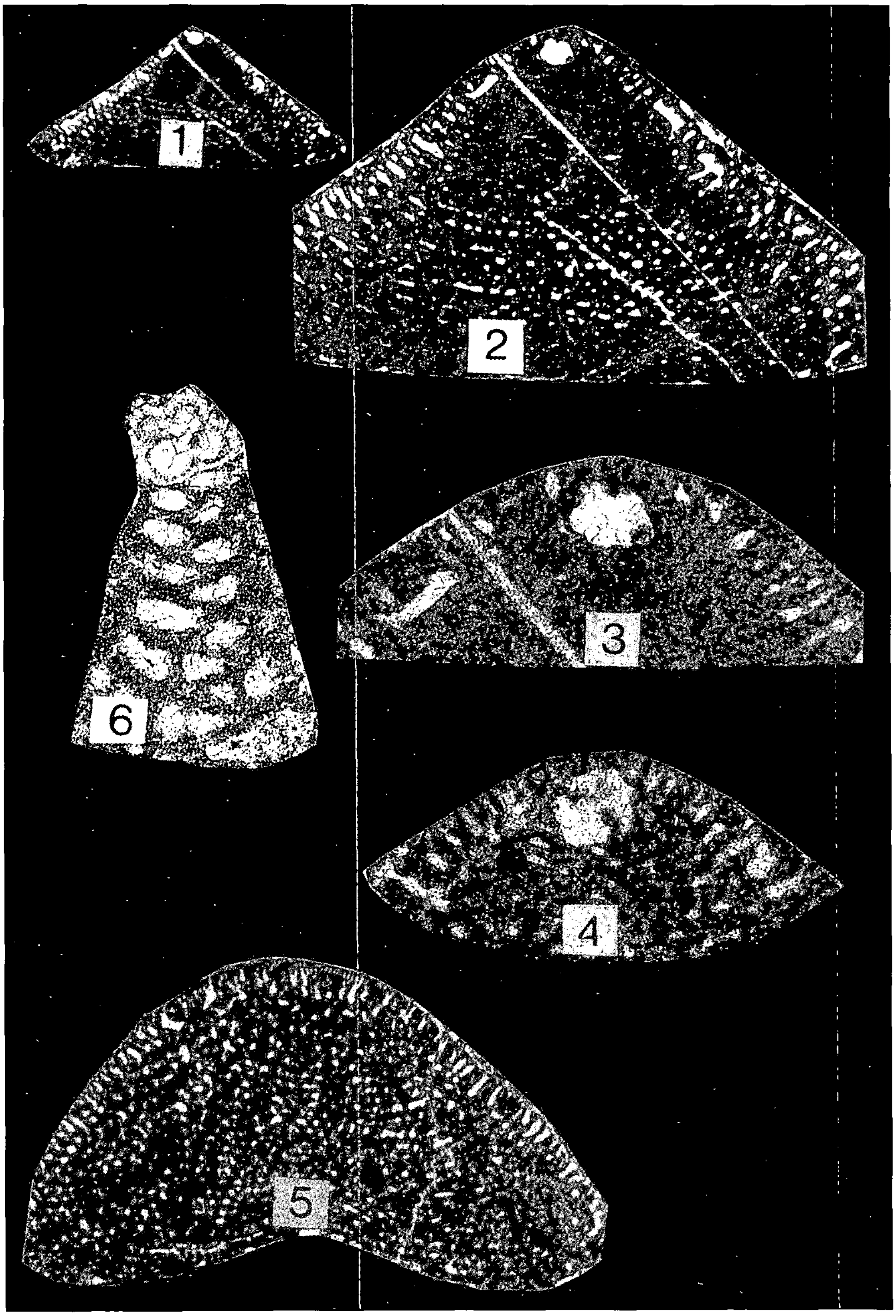
rendelkezésünkre. Ezekek madárszemes struktúrájú árapályövi loferitek és édesvízi charás mikritek, rétegtani besorolásra alkalmas ősmaradványokat nem tartalmaznak, jelzik viszont a csekély vízszintet és a platform kiemelt helyzetét.

Hasonló rétegsorokat (barrémi–apti) tártak fel a Bánát, Bánság aljzatát harántoló fúrások (ČANOVIĆ–KEMENCI 1988), a Duna–Tisza közi fúrások (CSÁSZÁR et al. 1983, BÉRCZINÉ MAKK 1986) és a közép-tiszántúli szénhidrogénkutató fúrások. Ezekről a feltorlódott, átbuktatott rétegsorokról elsőként PAP S. (1990) számolt be. Az alföldi furások harántolták a Harsányhegyi Bauxit Formációt, a nagyvastagságú alkáli bazaltot és agglomerátumot (Mecsekjánosi Bazalt Formáció), továbbá a Szársomlyói Mészkő Formációt is.

A Lippó L–2 fúrást a műszaki ellenőr a Nagyharsányi Mészkő F. átfúrása előtt leállította. A felső szakaszt teljes szelvénnyel fúrták, így innen sem a feküre, sem a fedőre, sem a Nagyharsányi Mészkő legidősebb képződményeire nincsenek adataink. Ezekre a képződményekre vonatkozó adatokat csak a Harsány-hegyi kőfejtő Nagyharsány–1 jelű felszíni sztratotípus szelvényből és annak referencia szelvényeiből extrapolálhatunk.

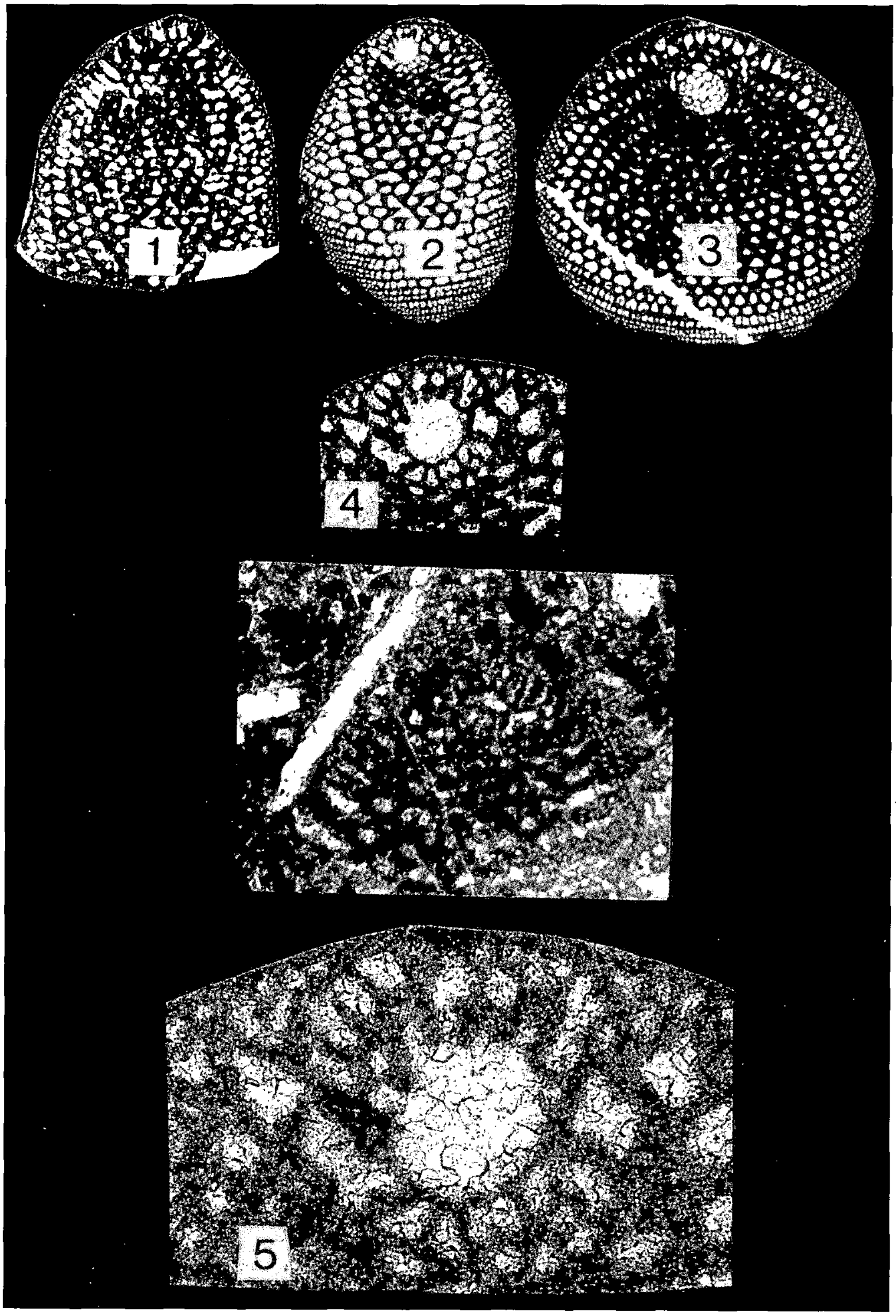
A Nagyharsányi Mészkő rétegtani terjedelme a felszíni sztratotípus szelvényben a felső-berriasi/alsó-valangini határtól a felső-aptiig (gargasi) terjed (BODROGI 1990, 1991a, 1993, BODROGI et al. 1993, 1994). A kőfejtő udvarán 1986-ban mélyült Nagyharsány–1 (nem azonos a Nah–1 jelű fúrással) fúrási referencia szelvény átfedéssel feltárta a Nagyharsányi Mészkő felső szakaszát (felső-apti–középső-albai), továbbá a Bissei Márga Formáció (a *Rotalipora appenninica* Zónába tartozó, felső-albai, azaz alsó-vrakoni) kihengerelt, vékony sávját, majd a Bissei Márgára feltolva alsó-apti (bedouli), *Praeorbitolina cormyi* Zónába tartozó urgon mészkövet tárt fel a feltolódás mentén. Összegezve: a Nagyharsányi Mészkő rétegtani terjedelme sztratotípus területén, a nagyharsányi Harsány-hegyen foraminiferák és mészalgák alapján a felső-berriasi/alsó-valangini határtól a középső-albaiig terjed (*az Orbitolina (M.) texana–Orbitolina (M.) subconcava* Zónáig (sensu SCHROEDER–NEUMANN 1985). Ugyanitt több bauxitkutató szelvényben, mind a bauxit fedőben, mind a bauxit feküben (a Szársomlyói Mészkő felső szakasza; BODROGI–KNAUER 1992; későbbiekben a Szársomlyói Mészkő Várhegyi Tagozata, BODROGI 1993) megtaláltuk a teljes berriasit átfogó zónajelző index fossziliát, a *Protopeneroplis trochangulata* SEPTFONTAINE fajt (*P. trochangulata* Taxon Tartomány Zóna SEPTFONTAINE 1974). Mivel a bauxit fedőben nem fordult elő eddig a valanginiben belépő *Protopeneroplis banatica* és a *Montsalevia salevensis*, ezért eddig nem tudtuk elhatárolni a felső-berriasi/alsó-valangini képződményeket. A bauxit feküben is előfordult a berriasi *Protopeneroplis trochangulata*, de nem fordult elő benne a titon korú *Protopeneroplis striata*. Mindezek alapján azt a következtetést vonhatjuk le, hogy az egy évtized alatt összegyűjtött foraminifera és mészalga vizsgálati eredményeink a Harsányhegyi Bauxit fedőjét illetően LÓCZY (1912, 1913, 1915) és TELEGDI ROTH (1930) korbesorolását erősítik meg, a bauxit fekü- és fedőviszonyaira vonatkozóan pedig RAKUSZ (1930, 1937) és NOSZKY (1957) korbesorolásaival egyeznek meg. A Nagyharsányi Mészkő Formáció azonban nem autochton képződmény, hanem takaró, mely rá van tolva a Mecsek–Apuseni, vagy Tisza tektonikai egységre (BODROGI et al. 1994b).

Plate I — I. tábla



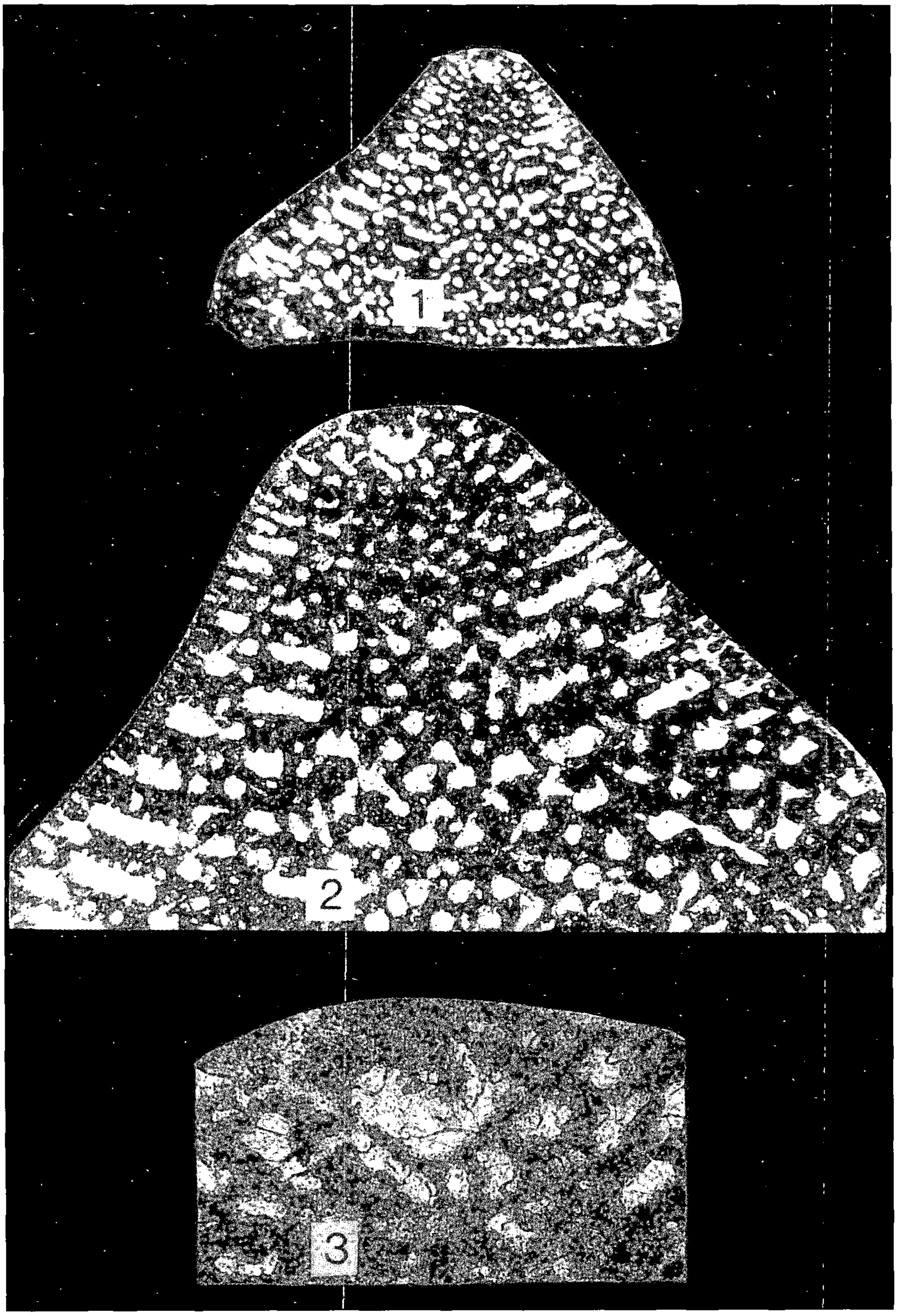
1–3. *Palorbitolina (E.) lenticularis* (BLUMENBACH), 839.6 m; 1. 8×; 2. 32×; 3. 50×.
4. *Palorbitolina (E.) charollaisi* SCHROEDER et CONRAD, 839.0 m, 50×.
5. *Palorbitolina* cf. *lenticularis* (BLUMENBACH), 839.6 m, 50×; subaxial section — tengelyközeli metszet.
6. *Sabaudia auruncensis* (CHIOCCHINI et DI NAPOLI ALLIATA), 1980 m, 50×; axial sagittale section of small specimen showing proloculus and its three post-embrionic chambers — kisméretű példány nyílalakú tengelymetszete, kezdőkamrával és három posztembrionális kamrával.

Plate II — II. tábla



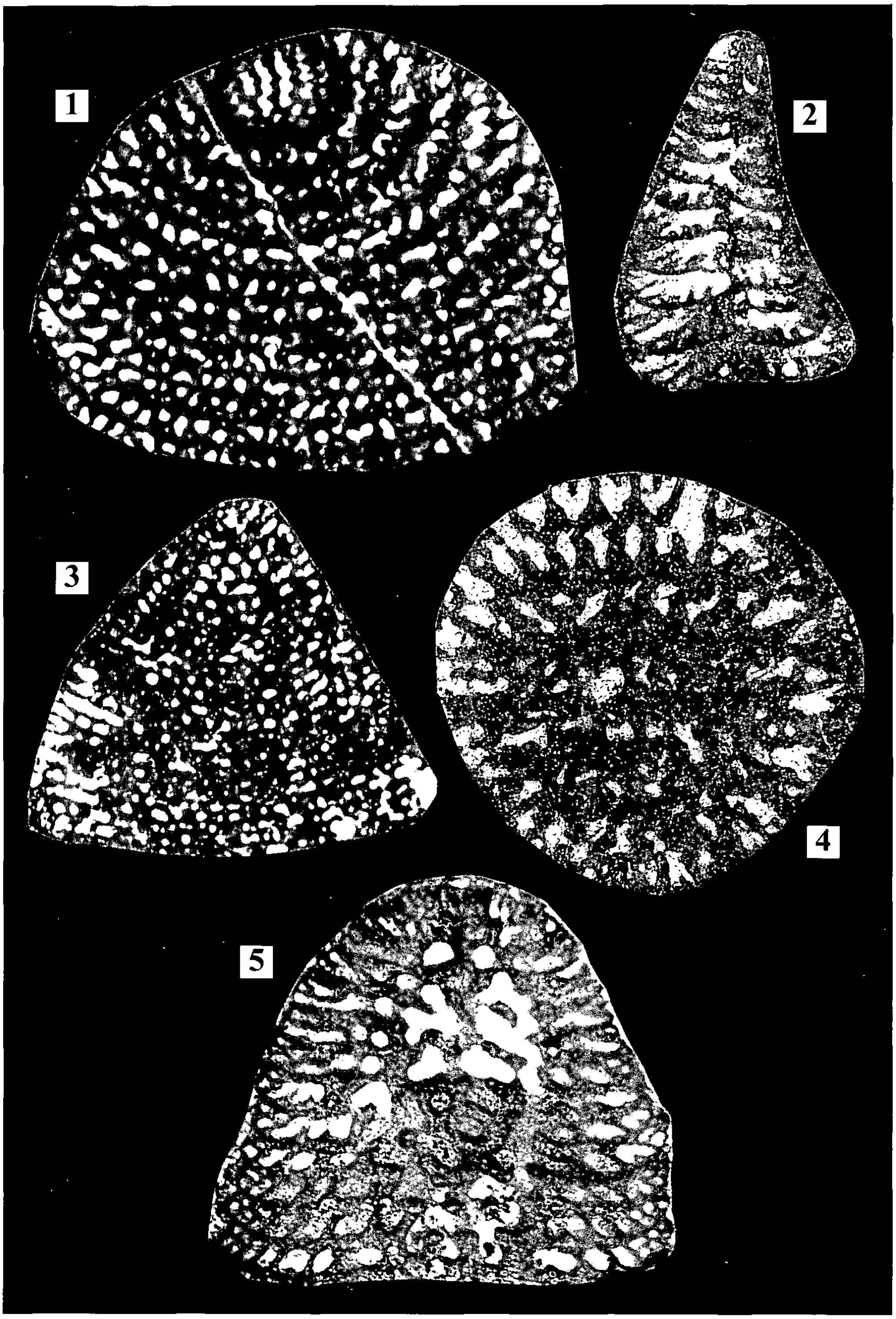
1–4, 6. *Orbitolina (M.) texana* (ROEMER), 1190 m; 1–2. 20×; 3. 32×; 4. 50×; 6. 128×.
5. *Orbitolina (M.) subconcava* LEYMERIE, 1200 m, 50×.

Plate III — III. tábla



1–3. *Orbitolina (M.) parva* DOUGLAS, 1040 m; 1. 32×; 2. 50×; 3. 128×.

Plate IV — IV. tábla



1. *Orbitolina (M.) pervia* Douglas, 1197 m, 50×.
2. *Sabaudia capitata* Arnaud-Vanneau, 841.6 m, 50×, Upper Barremian.
3–4. *Simplorbitolina* ex. gr. *manasi-conulus;* 3. 1187 m, 30×; subaxial section — tengelyközeli metszet; 4. 1200 m, 50×; basale section — talpi metszet.
5. *Dictyoconus pachymarginalis* Schroeder, 1020 m, 50×, Upper Aptian (Gargasian).

Plate V — V. tábla

1. *Orbitolina (M.) texana* (ROEMER), 1320 m, 34×; axial section, Lower Albian — tengelymetszet, alsó-albai.
2. *Simplorbitolina* cf. *manasi* CIRY et RAT, 1019 m, 54×; subaxial section — tengelyközeli metszet.
3. *Simplorbitolina* cf. *manasi* CIRY et RAT, 1200 m, 54×; basal section? — talpi metszet?.

4–6. *Simplorbitolina* cf. *conulus* SCHROEDER; 4. 1019.5 m, 54×; tangential section — tangenciális metszet; 5. 1019.5 m, 54×; part of a subaxial section — tengelymetszet része; 6. 1010 m, 54×.

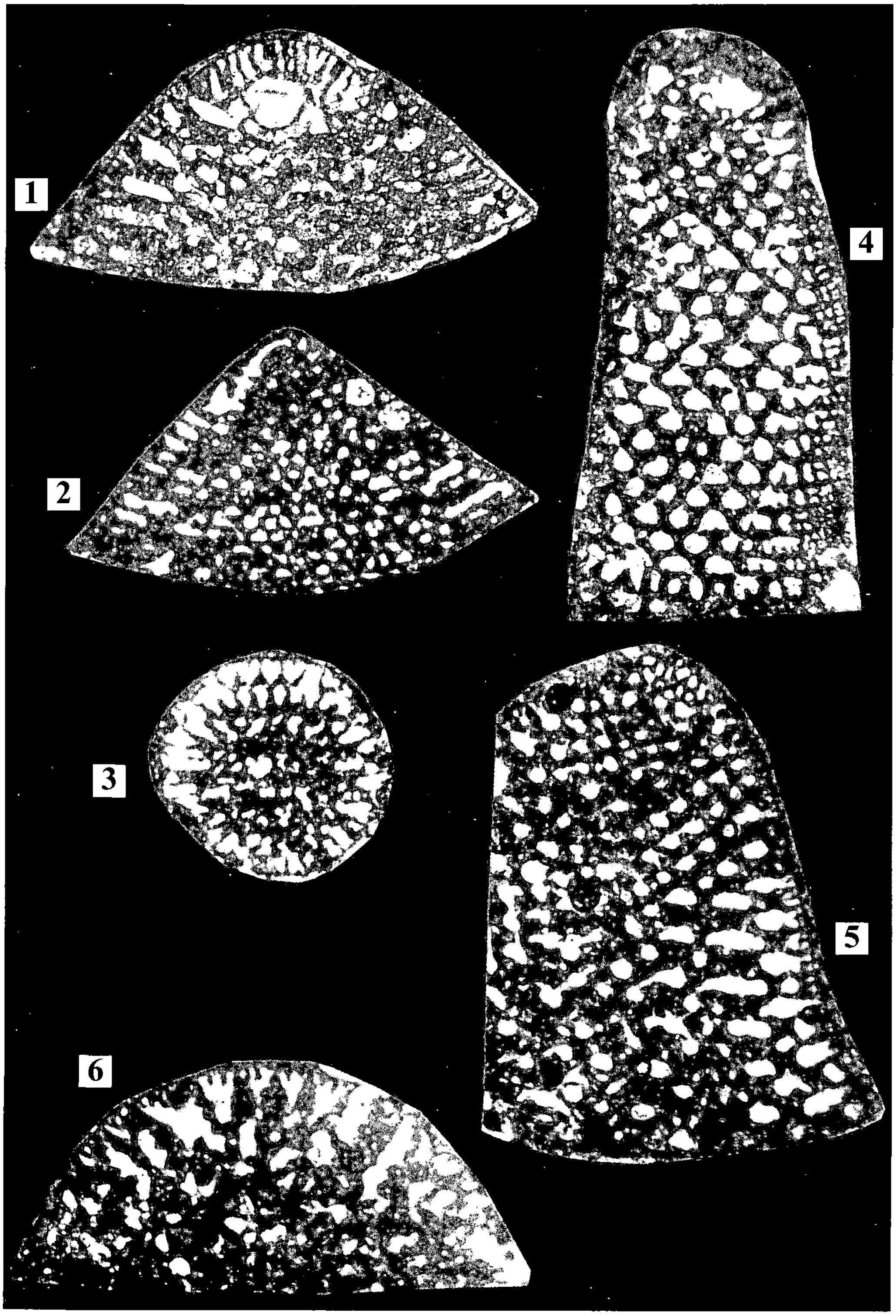


Plate VI — VI. tábla

1–7. *Sabaudia auruncensis* (CHIOCCHINI et DI NAPOLI ALLIATA).

1–4. Subaxial sections, and the Fig. 4 shows transverse section, too. All figs. are 134×. — Tengelyközeli metszetek, a 4. képen keresztmetszet is látható. Valamennyi 134×; 1. 1890 m, 2. 1980 m, 3–4. 2000 m.

5–6. Axial sagittal sections, the first embrionic chambers have been eroded away. Both of figs. are 134×. — Tengelyközeli metszetek, az első embrionális kamrák lekoptak. Mindkét kép 134×.

7. Two specimens, subaxial sections (thin section No 1980/a) 1980 m. — Két példány tengelyközeli metszete (1980/a jelű vékonycsiszolat); 54×.

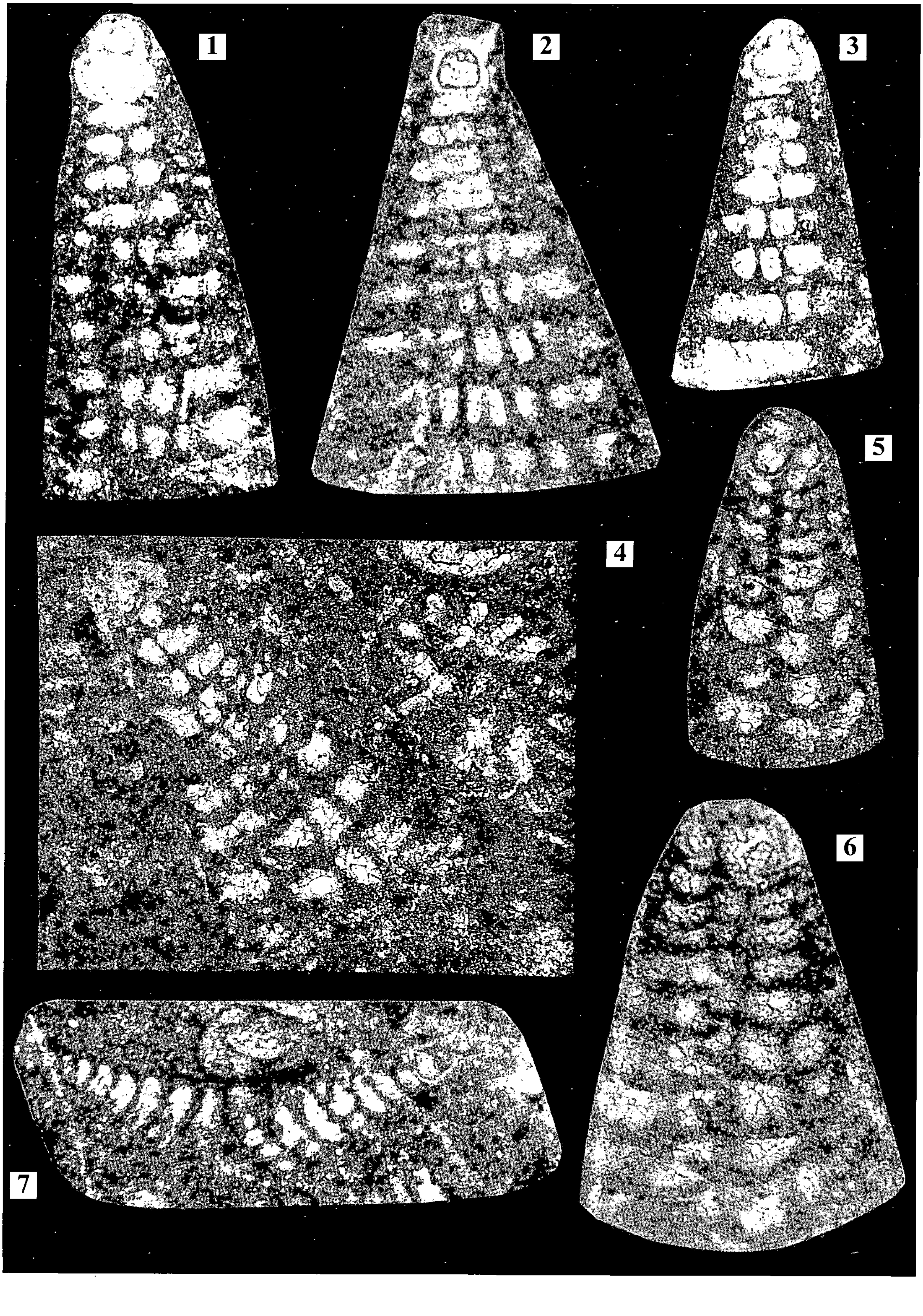

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Plate VII — VII. tábla

1. *Pseudotriloculina* sp., 1390 m, 50×.
2. *Quinqueloculina lirenangulata* LOEBLICH-TAPPAN, 1390 m, 50×.
3. *Quinqueloculina robusta* NEAGU, 1390 m, 50×.
4. *Triloculina* sp., 1390 m, 50×.
5. *Glomospirella* sp., 1390 m, 50×.
6. *Nezzazatinella* cf. *macoveii* NEAGU, 841.6 m 136 ×.
7. *Mayncina* cf. *termieri* HOTTINGER, 839.8 m, 50 ×.
8. *Arenobulimina meltae* KOVATSEVA, 1190 m, 128 ×.
9. *Arenobulimina* sp., 836.8 m, 128×.
10. *Pseudolituonella* cf. *gavonensis* FOURY, 1120 m, 50×.
11. *Glomospirella urgoniana* ARNAUD-VANNEAU, 841.6 m, 128×.
12. *Novalesia* sp., 1200 m, 50×.
13. *Novalesia* aff. *distorta* ARNAUD-VANNEAU, 1200 m, 50×.
14. *Haplophragmoides* sp., 836.8 m, 128×.
15. *Bolivinopsis* sp., 1200 m, 50×.

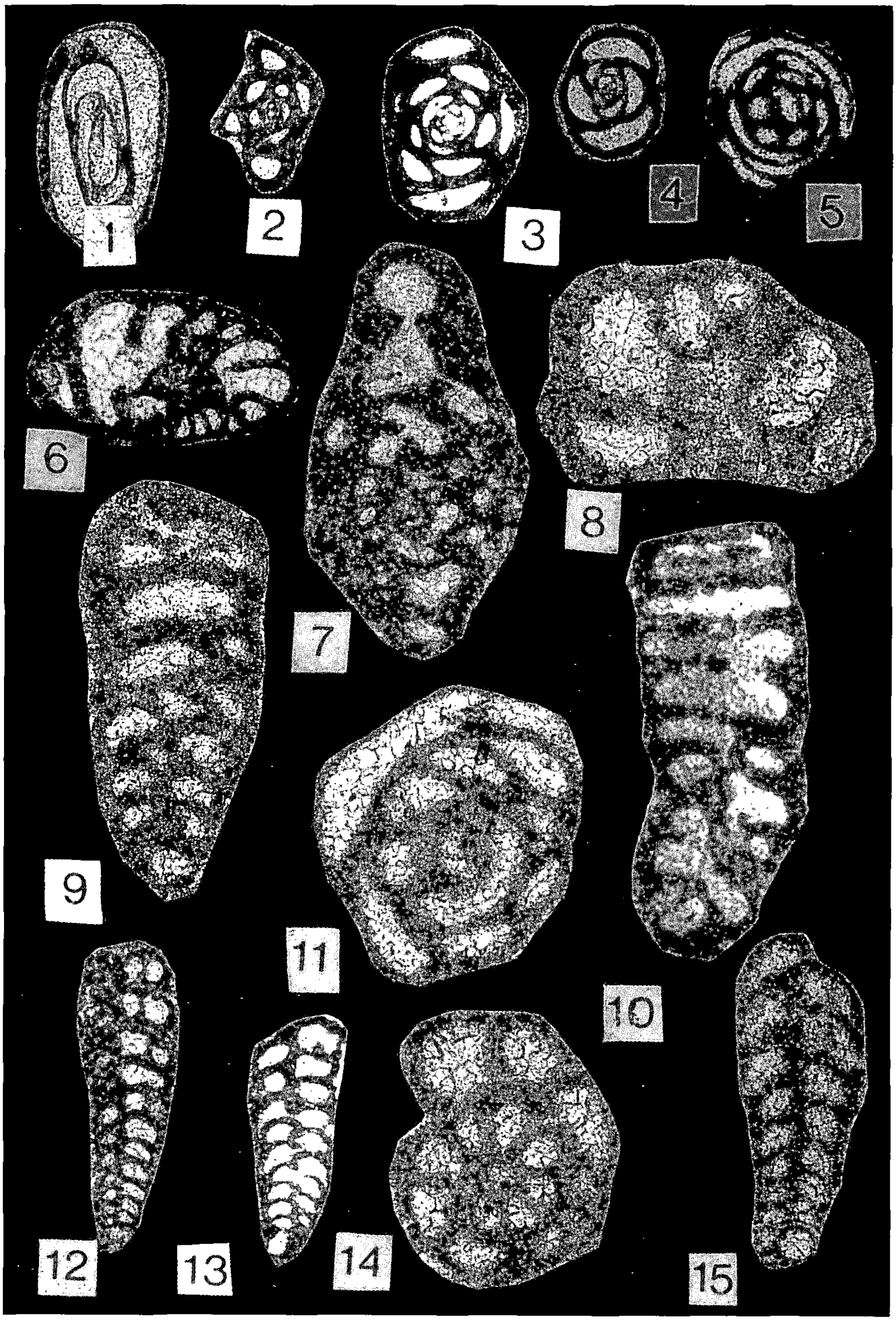
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Plate VIII — VIII. tábla

1. *Sabaudia briacensis* ARNAUD-VANNEAU, 1710 m, 136×; axial section — tengelymetszet.
2. *Sabaudia capitata* ARNAUD-VANNEAU, 1980 m, 136×; axial section — tengelymetszet.
3. *Simplorbitolina* gr. *conulus* SCHROEDER, 960 m, 34×; axial section — tengelymetszet; Matrix: strongly tectonised fine bioclastic micrite — tektonikusan erősen töredezett finomszemű biomikrit alapanyag.
4. *Sabaudia capitata* ARNAUD-VANNEAU, 841.4 m, 136×; axial sagittal section — nyílalakú tengelymetszet.
5. *Sabaudia minuta* (HOFKER), 2000 m, 136×; axial section — tengelymetszet.
6. *Arenobulimina kochleata* ARNAUD-VANNEAU, 1250 m, 136×; axial section — tengelymetszet.
7. *Glomospirella* cf. *urgoniana* ARNAUD-VANNEAU, 1750 m, 136×; axial section — tengelymetszet.

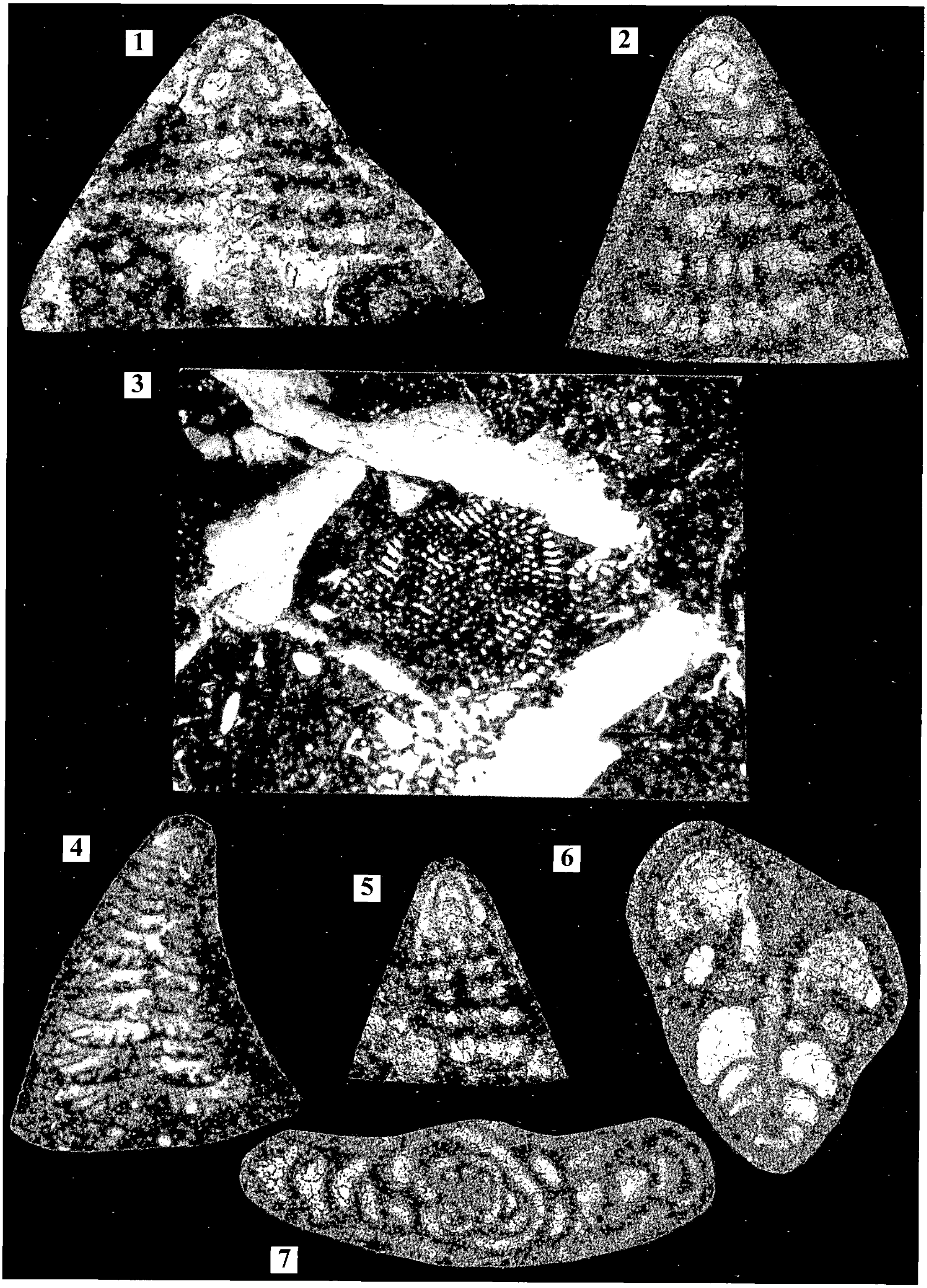
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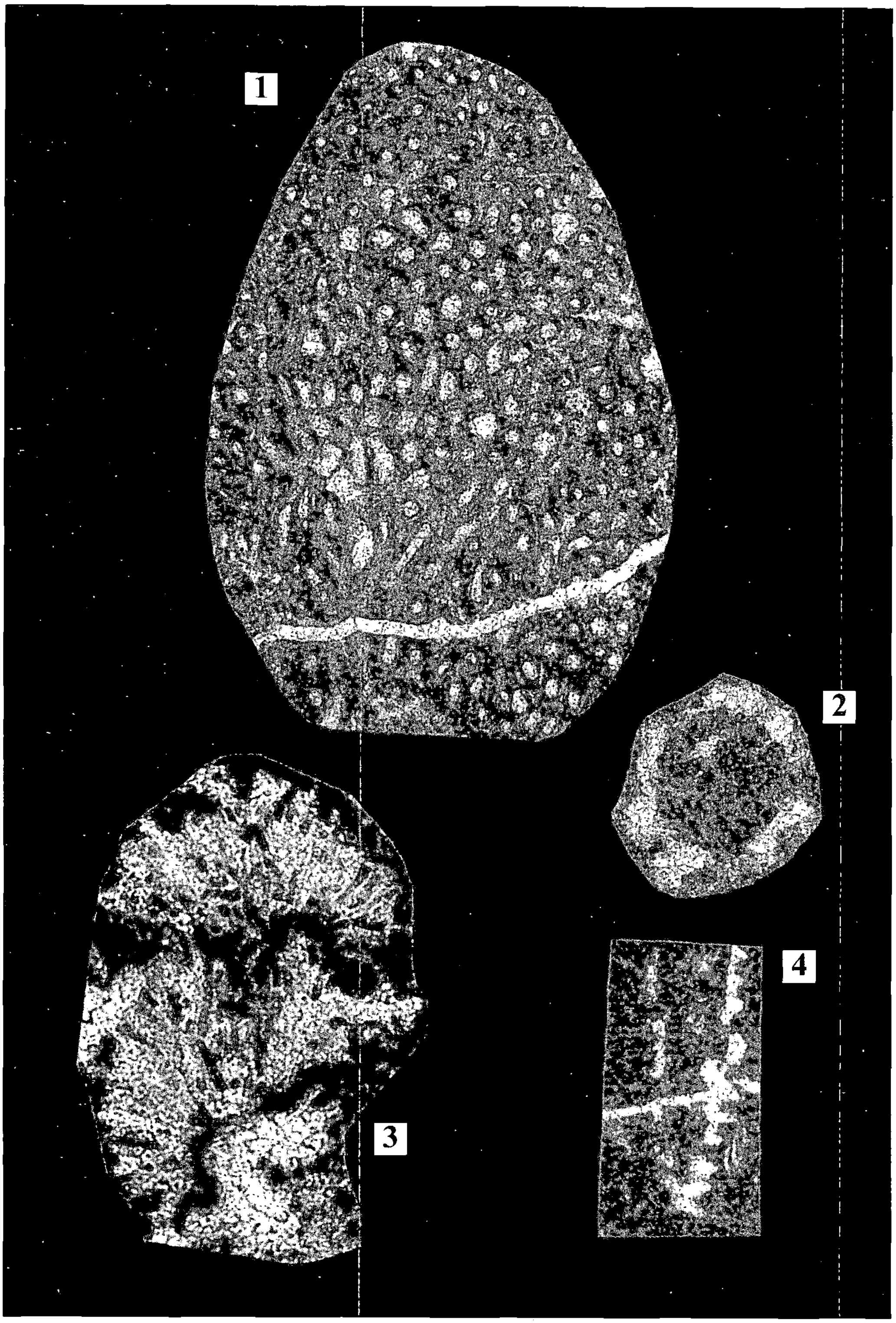
Plate IX — IX. tábla



1. *Pycnoporidium lobatulum* YABE et TOYOMA, 1200 m, 54×.
2. *Ethelia alba* (PFENDER), 890 m, 54×, Upper Barremian — felső-barrémi.
3–4. *Salpingoporella* cf. *melitae* RADOIČIĆ, 841.6 m, 54×; Upper Barremian — felső-barrémi; 3. Equatorial section — egyenlítői metszet; 4. Axial section — tengelymetszet.

ANN. REP. OF THE GEOLOGICAL INSTITUTE OF HUNGARY, 1992–1993/II: 53–56 (1999)

RELATIONSHIP BETWEEN GEOLOGICAL SETTING AND TOXIC ELEMENT ENRICHMENTS OF NATURAL ORIGIN IN HUNGARY

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Manuscript received in 1994.

Keywords: ? environmental geology, pollution, geochemical anomaly, geochemical map, antimony, arsenic, lead, mercury, concentration, toxicity, Tokaj Range

UDC: 504.064(234.373.3/.5Tokaj) 549.24+549.25+549.29(234.373.3/.5Tokaj) 912:550.4(234.373.3/.5Tokaj)

The state of the environment is jointly determined by the geological setting namely the element enrichment of natural origin in rocks and soils and by the additional pollution due to human activity. The original concentrations of elements in rocks and soils are sometimes much higher than guide-line values in regulations on soil contaminants. Formations of considerable surface extent and potentially toxic element enrichments of natural origin (As, Hg, Pb, Sb) are outlined using knowledge of the geology and metallogeny of Hungary and by the use of existing geochemical data. Based on a regional geochemical survey of the Tokaj Range (NE Hungary) actual baseline data are given to characterise the geochemical environment of the area.

Introduction

The effects on nature of industrial and agricultural activities are generally investigated in environmental pollution studies. But the fact that several kinds of rocks and soils are found on the surface with different chemical compositions must also be taken into consideration. This natural background i.e. the geological, petrological and geochemical characters (the original element content of rocks and soils) must be investigated before evaluating manmade pollution patterns.

Methods

The abundances of elements in the main rock types (Turekian 1961) show that certain kinds of rocks seem to have a high content of some potentially toxic elements. Only rough information is given by these rock abundance values, established for world-wide comparison, as to the actual element contents to be expected in our environment. That is why specific geochemical investigations are necessary (Salminen 1991) in order to determine the actual geochemical nature of rocks (Connor 1990) and to establish baseline data by the use of geochemical mapping methods (Darnley 1991). With all this in mind the geological formations with possible enrichment in toxic heavy elements are described first, then environmental geochemical maps are shown for the Tokaj Range [NE Hungary] (Hartikainen, Horváth 1992) taking into account the guide-line values for admissible metal concentrations in agricultural soils (Adriano 1991). Formations with possible toxic heavy element content were outlined using the geological map (scale 1:500,000) of Hungary. The range of elements was determined by semi-quantitative analytical methods while quantitative analytical data obtained through a gold-silver exploration project were used to study the distribution of environmentally important elements in the soils of the Tokaj Range. For this purpose the area was subdivided into small hydrographic basins (cells) of about 4 sq.km. 1050 individual samples were collected from these cells then composited to 207 samples for analyses.

The distribution of geological formations with possible toxic element content in Hungary

The formations outcropping in Hungary were classified according to geochemical data available for certain potentially toxic elements like arsenic, mercury, lead and antimony and using some basic geochemical parameters for comparison and evaluation (Fig. 1, Table 1).

75% of the territory of Hungary is covered by Quaternary clastic sediments. These are generally free from toxic element enrichment near the surface but waters with high arsenic content are derived from these formations in the SE part of Hungary (Fig. 1, A).

Tertiary formations consisting mainly of detrital sediments and the Mesozoic carbonate formations cover

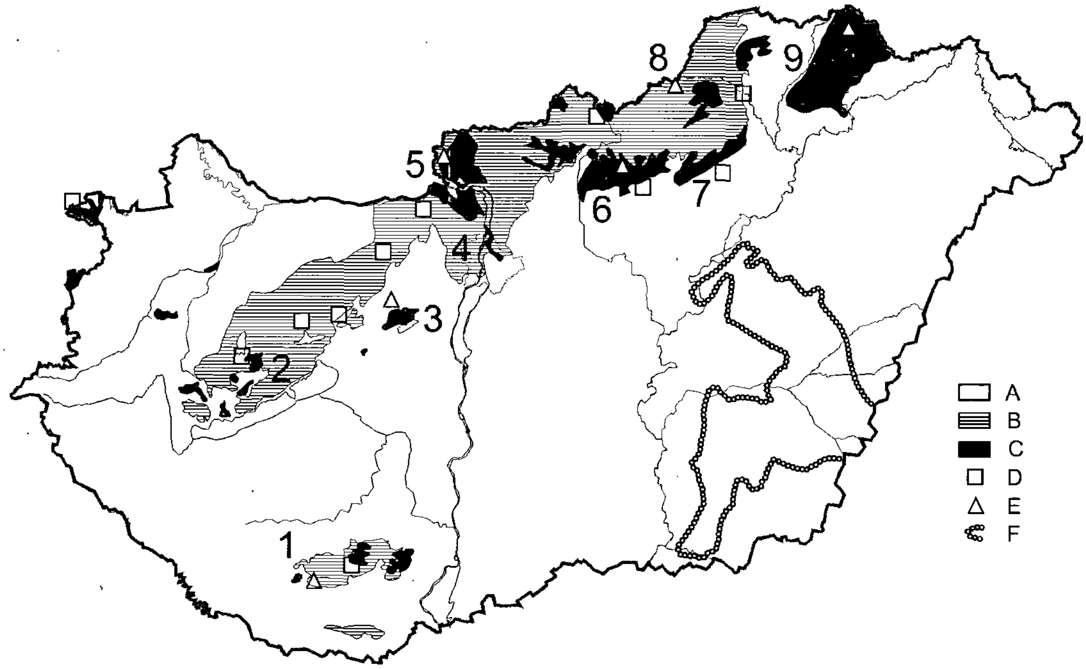

Fig. 1. Groups of geological formations with potentially toxic heavy element content in Hungary (As, Hg, Pb, Sb)
A = Quaternary clastic sediments free from toxic element enrichment, B = Tertiary clastic and Mezozoic carbonate formations with only local toxic element enrichments, C = Magmatic (granitic and volcanic) and metamorphic formations with frequent toxic element enrichments, D = Coals, E = Ore mines (closed), F = As-waters; 1. Mecsek Mts, 2. Balaton Highlands, 3. Velence Hills, 4. Buda–Pilis Mts, 5. Börzsöny Mts, 6. Mátra Mts, 7. Bükk Mts, 8. Rudabánya mine, 9. Tokaj Range, 10. Sopron Mts

1. ábra. Potenciálisan toxikus nehézelem tartalmú (As, Hg, Pb, Sb) képződménycsoportok Magyarországon
A = Toxikus elemdúsulástól mentes fiatal törmelékes képződmények, B = Kainozoos törmelékes és mezozoos karbonátos összletek, csak helyi toxikus elemdúsulásokkal, C = Gyakori toxikus elemdúsulást tartalmazó magmás (gránitos és vulkáni) képződmények, D = Szénbányák, E = Ércbányák, F = Arzénes vizek

large areas (Fig. 1, B). In the regional sense they are also free from toxic enrichments. However geochemical processes following their deposition resulted in toxic element anomalies which are noticeable but only local in character. Subsequent mineralisation enriched As, Sb and Pb locally in Triassic formations of the Mecsek Mountains, Balaton Highlands, Bükk Mountains and especially in the surroundings of Rudabánya, while due to hydrothermal activity Hg anomalies can be found in the Buda–Pilis Mountains. (FÖLDVÁRINÉ VOGL 1970, CSALAGOVITS 1973, RAINCSÁK 1984, NAGY, PELIKÁN 1970) as seen on Fig. 1. Coal and ore mines are also shown representing possible point sources of environmental pollution. Among the igneous formations (Fig. 1, C) the oldest granitic rocks have only limited surface extent but noticeable anomalies of toxic element content are associated with these outcrops. 15 to 20% of the soils of the Velence Hills for example, contain more arsenic and antimony than the threshold value for agricultural soils. Hydrothermal alteration zones of the volcanic formations in the Börzsöny, Mátra and Tokaj Range which are mineralised, have the highest enrichments of the elements studied. In these regions the geochemical environment is characterised in many places by As, Sb, Pb and

Table1 — 1. táblázat

Natural and admissible abundances in ppm for some toxic elements — Néhány toxikus elem természetes, ill. megengedett koncentrációja (ppm)

	As	Hg	Pb	Sb
Earth's crust [TUREKIAN, WEDEPOHL 1991] Földkéreg	1.7	0.08	20	0.5
Permitted metal concentration in soils [ADRIANO 1991] Megengedett fémkoncentráció a talajban	20	2	100	5
Tokaj Range, regional average [HORVÁTH et al. 1991] Területi átlag a Tokaji-hg.-ben	6.2	0.22	42	<1

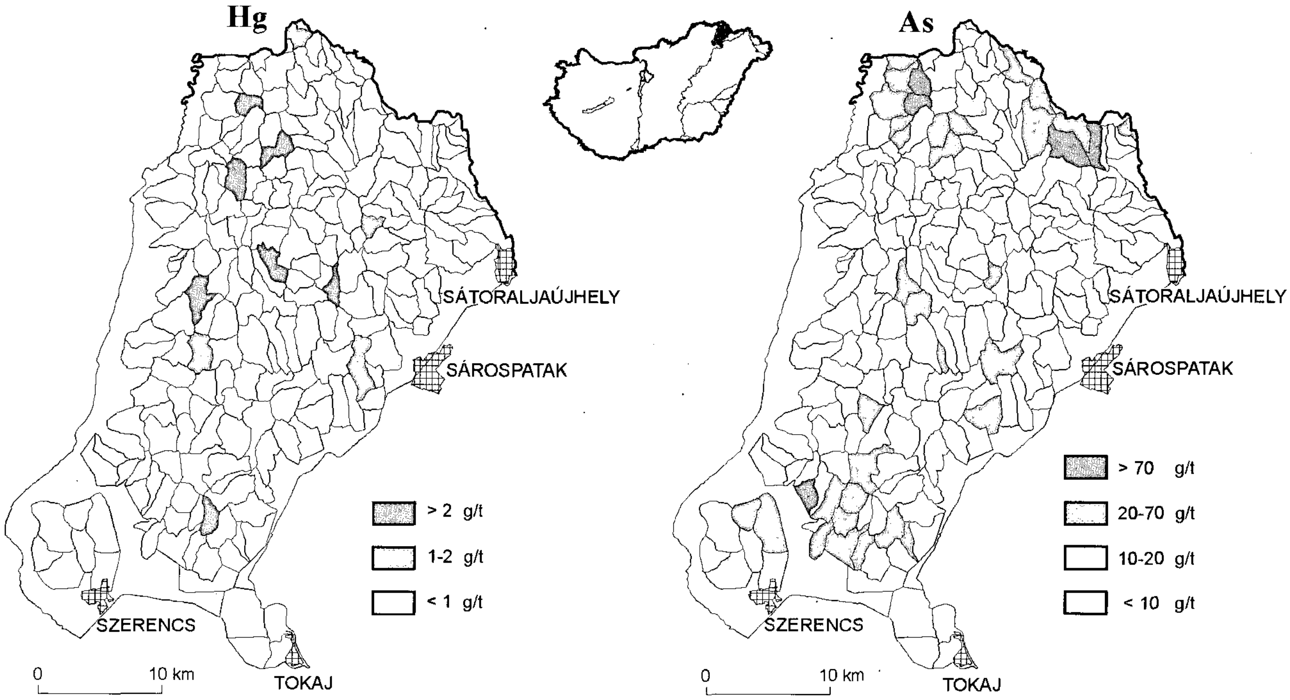

Fig. 2. Distribution of mercury and arsenic in the soils of the Tokaj Range (NE Hungary)
2. ábra. A higany és az arzén eloszlása a Tokaji-hegység talajaiban

sometimes Hg contents well above the accepted limit (Table 1) and this is a basic natural condition. As an example of the details of the geochemical patterns of such an area the results for mercury and arsenic of the reconnaissance geochemical survey of the Tokaj Range are shown on Fig. 2. Table 1 contains the regional averages. The highest average concentrations in the soils of a cell are 6.6 ppm for mercury and 470 ppm for arsenic. The permitted metal content according to German standard are 2 ppm and 20 ppm respectively. Areas exceeding these limits of toxic element contents may show some damage to certain species of plants and animals.

Conclusions

It is possible in environmental studies to get a rough estimate of the geochemical background of a certain area by using geological maps and the abundance values of elements for the different types of rocks. But the contamination caused by human activity can only be properly evaluated if actual baseline data are known for the area and the elements under study. The regional geochemical survey and the sampling density used in the Tokaj Range are suitable for the characterisation of the geochemical state of the environment in a given area.

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A FÖLDTANI FELÉPÍTÉS ÉS A TERMÉSZETES EREDETŰ TOXIKUS ELEMDÚSULÁSOK KAPCSOLATA MAGYARORSZÁGON

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Tárgyszavak: környezetföldtan, szennyezés, geokémiai anomália, geokémiai térkép, antimon, arzén, ólom, higany, koncentráció, toxicitás, Tokaji-hegység

ETO: 504.064 (234.373.3/.5Tokaj) 549.24+549.25+549.29(234.373.3/.5Tokaj) 912:550.4(234.373.3/.5Tokaj)

A környezet állapotát a földtani adottságok, a kőzetek és a talajok természetes eredetű elemkoncentrációi és az emberi tevékenység szennyező hatása együttesen határozza meg. Magyarország földtani felépítésének, metallogéniájának, a meglévő geokémiai elemzési adatoknak az ismeretében körülhatároljuk azokat a nagyobb felszíni elterjedésben megismert képződményeket, amelyek területén és közvetlen környezetében előfordulhatnak jelentős természetes eredetű toxikus elemkoncentrációk (pl. As, Sb, Hg, Pb). A potenciálisan környezeti veszélyforrást jelentő földtani képződményekre célszerű nagyobb figyelmet fordítani a környezeti vizsgálatokban és a szennyeződések geokémiai értékelésekor. Vázlatos térképen tüntettük fel a fiatal törmelékes képződményeket, amelyek a toxikus elemdúsulásoktól mentesek, ábrázoltuk a kainozoos törmelékes és a mezozoos karbonátos összleteket, amelyekben csupán lokális, de esetenként jelentős toxikus elemdúsulásokat találunk, és elkülönítettük a magmás (gránitos és vulkáni) és kristályos kőzetek területét, ahol a toxikus elemek feldúsulását gyakorinak tekintjük. Geokémiai felvételre (talajmintázás, összetett minták képzése és vizsgálata kb. 4 km^2/összetett minta sűrűséggel) alapozva példaként bemutatjuk higanyra és arzénre a Tokaji-hegység környezetgeokémiai állapottérképét. A talajokban mért legnagyobb átlagos higany-koncentráció e hegységben 6,6 g/t, az arzéné 470 g/t. A német szabvány ezekre az elemekre a talajhigiénés határértékeket 2 ill. 20 g/t értékben szabja meg. Az ennél nagyobb átlagos elemtartalommal jellemezhető területrészeken feltételezhető egyes növény- és állatfajok károsodása.

ANN. REP. OF THE GEOLOGICAL INSTITUTE OF HUNGARY, 1992–1993/II: 57–63 (1999)

THE ALLOCHTONOUS BASEMENT SEQUENCE OF NORTH-EASTERN CUBA

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Manuscript received in 1993.

Keywords: nappe structure, ophiolites, dyke swarms, volcanic arc, folded structure, Cretaceous, Cuba

UDC: 551.432.7+551.24(729.1) 552.321.6(729.1) 551.762.3+551763.1(729.1)

The paleo-autochtonous deep basement of the Sagua de Tánamo–Moa–Baracoa zone of north-eastern Cuba is represented probably by the southern marginal edge of the Bahama Platform, that is supposed to be in the study area between 5 and 15 km depths below the surface, dipping to the SW (KAKAS et al. 1992). This continental basement is covered by an allochtonous nappe sequence of Upper Jurassic–Lower Cretaceous ophiolitic and of Cretaceous volcanic arc origin, that are piled upon each other by movements of mainly 320° and subordinately of 270° slip directions along moderately inclined slide surfaces.

The original tectonic setting of the Cuban ophiolites has not yet been studied sufficiently enough, although their basic features are similar to the East Tethyan ophiolites. Here the dyke swarm complex shows a peculiar ambiguity having the rather well defined morphological characteristics of the sheeted complexes, but with structural and contact relations closely associated with the Cretaceous volcanic pile.

In the study area the accessible 1.5 km thick upper part of the allochtonous sequence has a definite tectonic succession. The ophiolitic gabbros are in the deepest observable position, covered by fragmented, discontinuous sheets of the Cretaceous volcanic rocks of island-arc origin, while slabs of the ultrabasic rock bodies, up to 1000–1200 m thick, overlay both of them.

The allochtonous basement pile is covered by semi-autochtonous, clastic, olystostromic sediments, formed during the nappe movements (COBIELLA 1983) and by more recent neo-autochtonous volcanic–sedimentary formations.

Introduction

From 1987 until the end of 1990, as part of a bilateral scientific cooperation program, a Cuban–Hungarian expedition carried out geological mapping and mineral exploration un an area of 2491 sq.km in Guantánamo and Holguín provinces (Fig. 1) with the participation of about 20 specialists of both countries. This paper is based upon the results of these works (GYARMATI et al. 1990) although in several aspects represents the author's personal opinions.

General features

In the study area the oldest known basement sequence is represented by the allochtonous nappes of the Upper Jurassic–Lower Cretaceous ophiolitic complex and of the volcanic rocks of the Cretaceous island-arc system, piled upon each other along overthrust surfaces of low inclination angles. In about a third of the territory the basement is covered by the semi-autochtonous Upper Cretaceous and more recent autochtonous sedimentary strata (basins of Sagua de Tánamo, Palenque, plateau of Guaso, northern coastal zone).

In the north-eastern part of Cuba the deep basement of the allochtonous sequence is unknown, but considering the most recent interpretation of the latest gravimetric measurements by KAKAS et al. (1992) it is supposed to be at a depth between 5 and 15 km, sinking to the SW, with the Miraflores–Riito fault system as a major controller of its actual position (Fig. 2). The deep basement is represented probably by the marginal zone of the North-American continental plate. This idea is based both on geophysical interpretation and structural analogy of other parts of Cuba (ITURRALDE-VINENT 1984). It is also in accord with views that a metaterrigenous — carbonatic structural block, located to the SE of the territory, represents a fragment of the North-American continental plate (BREZSNYÁNSZKY et al. 1976, ITURRALDE-VINENT 1984, SOMIN, MILLAN 1981 etc.).

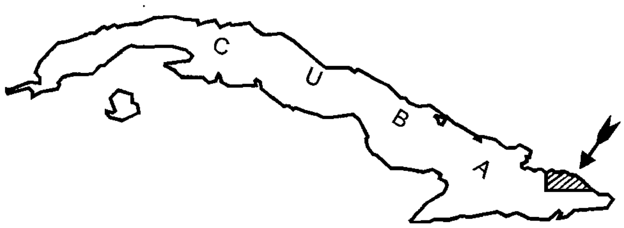

Fig. 1. Location of the study area
1. ábra. A vizsgált terület elhelyezkedése

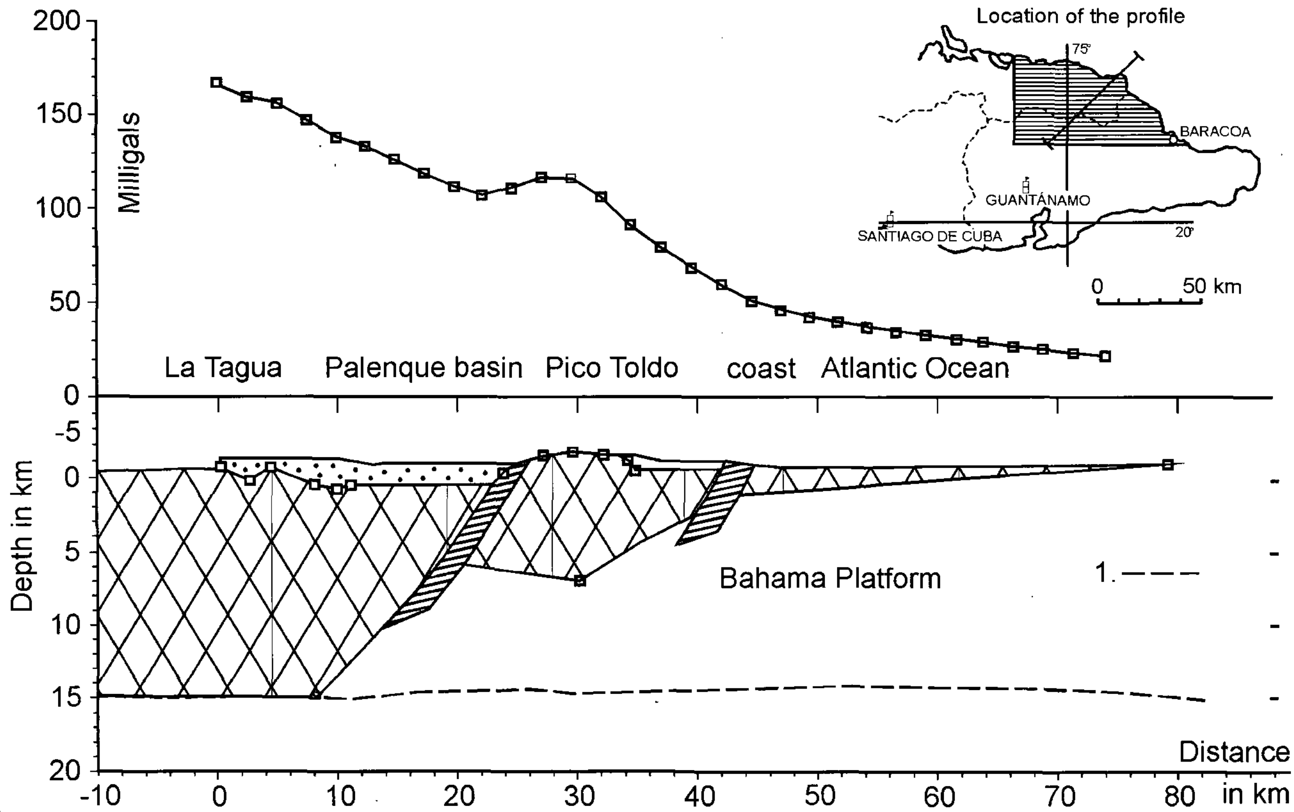

Fig. 2. Gravimetric model calculation and its interpretation (KAKAS et al. 1992)
1. Level of compensation

2. ábra. Gravimetrikus modell számítás és földtani értelmezése (KAKAS et al. 1992)
1. Izosztatikus kiegyenlítődési szint

The ophiolites

The overwhelming bulk of the allochtonous pile consists of the ophiolitic sequence, that can be correlated fairly well with the theoretical ophiolitic section of the ocean floor.

The lack of palaeomagnetic and trace element analysis data does not allow the proper evaluation of the original tectonic setting of the Cuban ophiolites so here we mention only 3 possible ideas about it:

a) One of the most accepted theories was elaborated by ITURRALDE-VINENT (1984), according to which the Cuban ophiolites were formed in back-arc basin environment.

b) The main geological features of the ophiolites of the study area correspond fairly well to the characteristics given by PEARCE et al. (1984) for supra-subduction zone ophiolites, (composition of the mantle and cumulate sequences, relative abundance of chromites etc.), that might be formed by processes of pre-arc spreading.

c) The structural and contact characteristics of the dyke swarm complex seem to refer to an island-arc origin according to MIYASHIRO's controversial theory (1975) or may refer to other phenomena e.g. the partial offscraping of the oceanic platform that was formed by the "still event" on the Caribbean plate between 130 and 80 M. years ago (DONELLY 1985, FRISCH et al. 1992).

Five genetical units were distinguished within the ophiolitic complex by our team in the study area while the occurrence of two others was considered as uncertain (Fig. 3):

— The tectonic ultrabasic rocks (1st layer) are characterised by harzburgites and dunites of massive internal structure, generally with a high degree of serpentinization, containing a few, small, fragmented lenses of podiforme chromite ore. Some large bodies of amphibolites were also observed (Monte Bueno structural block to the W of Sagua de Tánamo).

— The deep cumulates or cumulate ultrabasic rocks (2nd layer) are represented by various peridotites as well as by dunites and piroxenites. Their thickness is relatively small, hardly surpasses 1200–1300 metres, but they cover extensive areas (Cuchillas de Moa, –Toa, –Baracoa and Sierra de Maguey), as a consequence of the almost horizontal overthrust surfaces inside the allochtonous pile. Their subdivision:

Dunite zone (2a. layer): dunites with large podiform bodies of chromite, peridotites, mainly harzburgites and lherzolites (Mercedita, Amores, Cayo Guam, Miraflores).

Peridotite zone (2b. layer): peridotites, piroxenites, dunites, (Cuchillas de Moa, –Toa, –Baracoa, Sierra de Maguey).

Transitional zone (2c. layer): it is found between the gabbro and ultrabasic cumulate complexes and it is char-

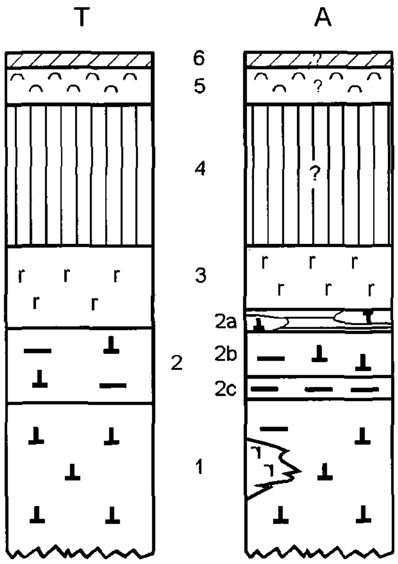

Fig. 3. Distribution of the ophiolites (with comparison of the theoretic [T] sequence and the actual [A] one)
T = Theoretic profile: 1. Tectonic peridotites, 2. Ultrabasic cumulates, 3. Gabbro cumulates, 4. Sheeted complex, 5. Pillow lavas, 6. Sediments; *A = Actual profile:* 1. Tectonic harzburgites, dunites, amphibolites; 2a. Dunites with chromite, 2b. Peridotite cumulates, 2c. Transitional zone, 3. Gabbro cumulates, 4. Cerrajon C. (?), 5. Pillow lavas (?); 6. Lenses of chert (?)

3. ábra. *Az ofiolit sorozat tagolása (az elméleti [T] és a tényleges [A] kifejlődés összevetésével)*
T = Elméleti szelvény: 1. Tektonikus peridotitok, 2. Ultrabázikus tömegek (kumulátok), 3. Gabbró tömegek (kumulátok), 4. Lemezes telér összlet, 5. Párnalávák, 6. Üledékes kőzetek; *A = Valós szelvény:* 1. Tektonikus harzburgitok, dunitek, amfibolitok, 2a. Krómitos dunitek, 2b. Peridotit tömegek (kumulátok), 2c. Átmeneti övezet, 3. Gabbró tömegek (kumulátok), 4. A Cerrajon Komplexum (?), 5. Párnalávák, 6. Tűzkőlencsék

acterised by a wide variety of peridotites, piroxenites, dunites and basic rock bodies (mainly gabbros, olivine-gabbros, gabbro-norites, troctolites) of irregular form, with sizes ranging from a few dozen to several hundred metres. In some areas this zone is represented by the alternation of 2–20 m thick, banded bodies of plagioclase bearing ultrabasic rocks and rocks of gabbroid composition (Riito, along the dirt road to la Melba, to the W of the Potosí chromite mine, to the SW of the Amores mine).

— The gabbro cumulates (3rd layer) are also widespread especially in the montainous region of the Cuchillas de Moa, Cuchillas de Baracoa, Loma Miraflores etc., represented mainly by huge bodies of gabbros, olivine gabbros, gabbro-norites and anortosites up to 50 sq.km of territorial extension.

— In the study area the presence of the sheeted complex (4th layer) is controversial. The dyke swarms of the Cerrajon Complex are regarded by several geologists as representatives of this ophiolitic unit, but as the dyke system has very close structural and complex contact relations with the volcanic-arc sequence, we give its description in part 3 of this paper.

— The pillow-lavas (5th layer) of amigdaloid basalts, hyaloclastites and basalts with chert lenses, located to the S of Loma Miraflores, may represent the highest ophiolitic unites. Lacking detailed data their tectonic setting is still uncertain.

The Createaceous island-arc formations

About 25% of the bulk of the allochtonous nappe structure system is comprised of volcanic rocks originated in the Cretaceous island arc volcanism that developed on ophiolitic basement and which is represented by the Santo Domingo and Sierra del Purial Formations as well as by the Cerrajon Complex.

In the composition of the Santo Domingo Formation the basic, intermediate or less frequently acidic volcanic, mainly pyroclastic rocks are predominant with subordinate sedimentary intercalations, while the Sierra del Purial Formation is generally regarded as the regionally metamorphosed variety of this same volcanic sequence (Adamovich et al. 1963, Knipper, Cabrera 1974, Nagy et al. 1983). The grade of its metamorphism is far from homogenous but it rarely surpasses the green schist facies and it is considered by most geologists as a result of the tectonic events that took place during the obduction process.

The Cerrajon Complex (informal unit) is represented by subparallel dyke swarms of mainly doleritic composition, with an areal extension of about 100 square km. Its macroscopic features are similar to that of the ophiolitic sheeted dyke complexes, but some geological evidence strongly suggest their volcanic origin:

a) The dykes invaded the cumulate ultrabasic basement (2nd layer) in swarms up to a few km depth, gradually diminishing in quantity towards the centre of the ultrabasic rock bodies. In the marginal zones of the dyke complex its rocks contain large amounts of xenoliths of ultrabasic rocks, that disappear in the internal zones of the dyke fields.

b) Sills and subvolcanic bodies of dolerites of similar composition have also penetrated the stratovolcanic sequence of the Santo Domingo Formation, inducing large scale thermal metamorphism in its tuffitic layers.

c) Logically enough the dyke swarms also have the same or very similar structural characteristics as the volcanogene sequence of the Santo Domingo Formation and their occurrences are limited generally to the same structural blocks (Fig. 4).

d) The petrochemical analyses also seem to point to volcanic origin (Figs. 5 and 6) although their diagnostic power was questioned by recent studies around the world.

The range of the SiO_2 and TiO_2 contents is in line with Miyashiro's normative (1975) suggested for the island-arc volcanic rocks. Although the dispersion of the FeO^{total}/MgO quota has a narrower range than the one established by Miyashiro, its value is similar to that of the Santo Domingo Formation, referring also to comagmatic relations between the dykes and volcanic rocks.

The dolerites of the dyke system have somewhat more acidic average composition than the normal island-arc volcanic rocks of the region with a bit higher alkali content. This may point to a slightly more advanced differentiation.

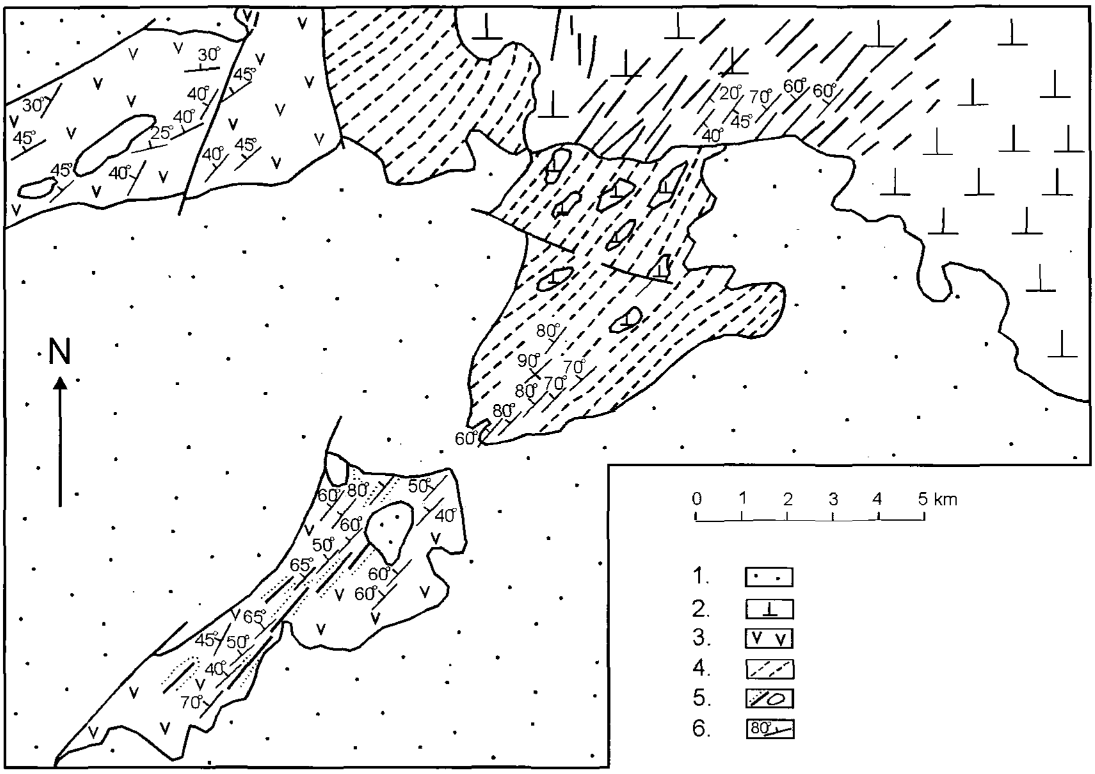

Fig. 4. Geological structure of the Cerrajon–La Tagua zone (San Luís de Potosí)

1. Covering formations, 2. Ultrabasic rocks, 3. Santo Domingo Formation, 4. Cerrajon Complex (with strike of the dykes), 5. Dolerite dykes and bodies (with contact methamorphism), 6. Dip of volcanogene formations, dykes and sills

4. ábra. A Cerrajon–La Tagua zóna földtani szerkezeti vázlata

1. Fiatal fedő képződmények, 2. Ultrabázisos kőzetek, 3. Santo Domingo Formáció, 4. A Cerrajon Komplexum (a telérek csapásirányával), 5. Dolerit telérek és testek (a kontakt metamorf zónák jelölésével), 6. Dőlésirányok a vulkanogén képződményekben, valamint a telérek és szillek dőlése

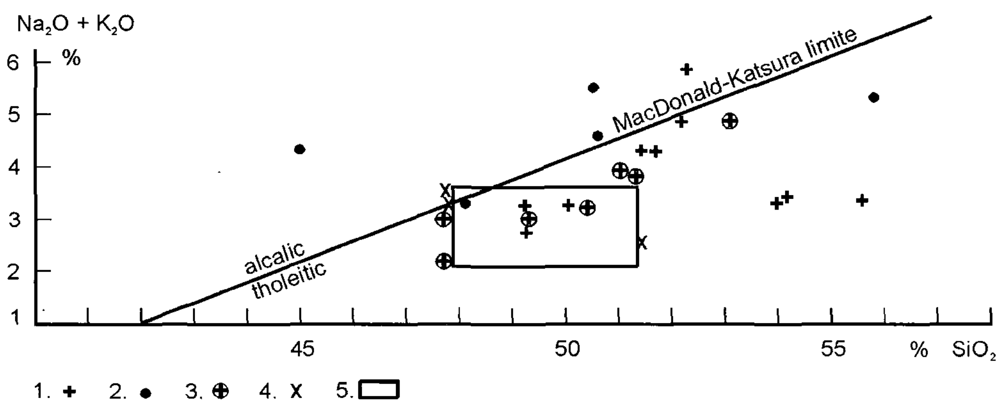

Fig. 5. Cross plot of Na_2O+K_2O versus SiO_2

1. Rocks of the Cerrajon Complex, 2. Dikes inside island-arc formations, 3. Rocks of the Santo Domingo Formation, 4. Rocks of the Sierra del Purial Formation, 5. Abyssic tholeites

5. ábra. Na_2O+K_2O tartalom az SiO_2 tartalom függvényében

1. A Cerrajon Komplexum kőzetei, 2. Telérek a szigetív eredetű formációkon belül, 3. A Santo Domingo Formáció kőzetei, 4. A Sierra del Purial Formáció kőzetei, 5. Abisszikus tholeitek

In the last few years "sheeted dykes" were also observed in several other parts of Cuba (FONSECA et al. 1984, ITURRALDE-VINENT 1988, ANDÓ in PENTELÉNYI et al. 1990 etc.), occasionally even with similar contact relations as described above. Similar features of the dyke systems are observed in some of the world's better known ophiolites and they may have the following implications:

a) It is highly improbable that the dyke system in question would correspond to oceanic or classic ophiolitic origin. That would suggest the development of multiple magmatic chambers (affecting even the mantle sequence!), with the no less far fetched supposition that the spreading zone, at one time or another, got below the volcanic-arc pile.

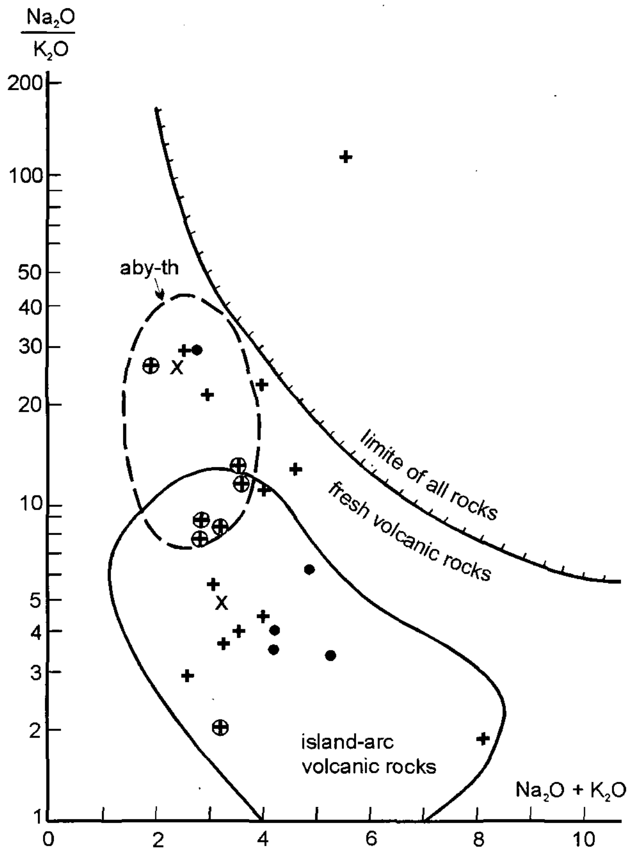

Fig. 6. Cross plot of Na_2O/K_2O versus Na_2O+K_2O

For legend see Fig. 5

6. ábra. Na_2O/K_2O tartalom az Na_2O+K_2O tartalom függvényében

Jelmagyarázat az 5. ábránál

b) PEARCE et al. (1984) proposed a theory, now widely accepted, about the supra-subduction zone ophiolites. This leads to the more likely explanation that the formations originated as intermediate type sheeted dykes. According to this new oceanic crust can be formed in the pre-arc spreading stage and later the spreading zone may gradually become a submarine volcanic arc. Later again, this arc may suffer partial destruction by back-arc spreading. He considers the majority of the overland ophiolites as having such origin.

c) The geological evidence can also be satisfied easily by a simple volcanic island-arc development process, that evolved on an ophiolitic basement (i.e. MIYASHIRO's not too widely accepted theory) or by the formation of a regional distension belt. Such has allegedly occurred during the "still event" in the Caribbean region with volcanic rocks strengthening and covering the Caribbean floor (DONELLY 1985).

Structural characteristics of the allochton

During the obduction process a seemingly chaotic allochtonous nappe pile system was formed along gently sloping overthrust slide surfaces. In the Cuchillas de Moa and Baracoa two main slip directions have been determined. The dominant one is of 320–340 degrees, generally with a northerly dip of 20–30°, however southern dips also can be observed in some places. The secondary slip surfaces have an azimuth of 260–270 with 20–30° dip. The internal structure of the Santo Domingo Formation and of the dyke complex is characterised by 320–340/40–80° dip (generally the dykes have greater inclination values, up to 90°), while that of the Sierra del Purial Formation by 280–310/30–60°. These structural characteristics seem to be in direct correlation with the local nappe movements.

Although at first glance the allochtonous pile seems to have a chaotic structure or a mosaic like at best, it has a certain internal ordering at least in the vertical sense. In the study area the gabbros of ophiolitic origin are found everywhere in the lowermost observable position (proved also by drill holes of up to 500 m depth). They are covered by the discontinuous nappe remnants of the Cretaceous volcanic rocks of the island-arc system, while the ultrabasic bodies always have a higher relative position (Fig. 7). This distribution pattern was established for the uppermost 1.5 km thick part of the allochtonous system, that was accessible for our observations in the Cuchillas de Moa and Baracoa region. However it should be noted that here the total thickness of the allochtonous pile may reach 5 or even 10 km.

While the structural features seem to be similar also in the zone of Sierra de Maguey, it is unlikely that they would be the same in the Monte Bueno block and farther to the West. Ultrabasic rocks were found at up to 5 levels in the boreholes NIPE–1–2 and PUERTO PADRE–1 in the form of sheets of gabbro and rocks of island arc origin.

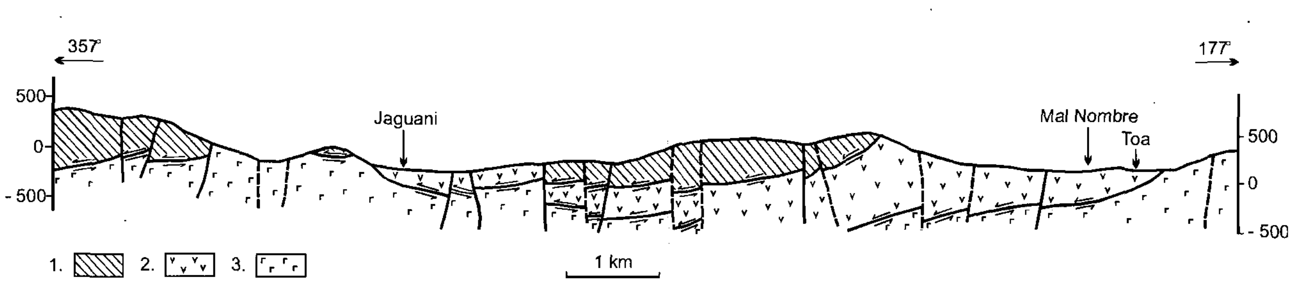

Fig. 7. Geological profile across the north-eastern part of the region

1. Ultrabasic rocks, 2. Cretaceous volcanic rocks of island-arc origin, 3. Gabbros

7. ábra. Földtani szelvény a vizsgált terület északkeleti részén keresztül

1. Ultrabázisos kőzetek, 2. Szigetív eredetű kréta vulkanogén sorozat, 3. Gabbrók

Semi-autochtonous formations

The collision that took place along the southern margin of the North-American continental plate, might have continued for a considerable time. But in the area of Sagua de Tánamo, Moa and Baracoa the main nappe movements occurred in the Campanian and Maastrichtian Stages, seemingly petering out completely in the lowermost part of the Paleocene. These tectonic events were presumably synchronous (Cobiella 1984, Cobiella et al. 1984) with the sedimentation of the semi-autochtonous La Picota and Micara Formations. The first of these is represented by coarse grained conglo-breccias, while the second one consists of an olystrostromic, polymict, sedimentary sequence. In the Micara Formation lithoclasts of ultrabasic rocks appear only in the middle of the section (PE–1 borehole), indicating also the relatively late arrival of the ultrabasic nappes to this area.

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ÉK-KUBA ALLOCHTON ALJZATÁNAK FÖLDTANI JELLEGEI

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Tárgyszavak: takaró szerkezet, ofiolit, telér raj, vulkáni szigetív, gyűrt szerkezet, kréta, Kuba

ETO: 551.432.7+551.24(729.1) 552.321.6(729.1) 551.762.3+551.763.1(729.1)

A Sagua de Tánamo–Moa–Baracoa közötti terület paleo-autochton mély aljzatát feltehetően a Bahama Platform déli elvégződése képviseli, amely itt mintegy 5—15 km közötti mélységben helyezkedik el DNy-i irányban süllyedő tendenciával (Kakas et al. 1992). Ezt a kontinentális lemez-peremet felső-jura–alsó-kréta ofiolitos és kréta vulkáni szigetív eredetű, feltorlódott allochton takaró sorozat fedi, amelyet 320° és alárendelten 270° irányú mozgások halmoztak egymásra lapos dőlésű csúszási síkok mentén.

A kubai ofiolitok eredeti tektonikai helyzetét nem ismerik kellőképpen, nincsenek megnyugtatóan tanulmányozva, bár hasonlóságuk a kelet-tethysi ofiolitokhoz szembeszökő. Itt a telérkomplexum azonban sajátos kettősséget mutat, mivel morfológiai jellegei

az ofiolitos lemezes telér összletekéhez állnak közel, szerkezeti és kontaktus viszonyai alapján viszont szorosan kapcsolódik a kréta vulkáni szigetív sorozathoz.

A vizsgált területen az allochton tömeg mintegy 1,5 km vastag felső része, amely felszínen vagy fúrásokkal egyáltalán hozzáférhető, jellegzetes egymásfölöttiséget, szerkezetet mutat. A legmélyebb helyzetűek az ofiolitos eredetű gabbrók, amelyeket a kréta vulkáni szigetív szakadozott, nem összefüggő takarója fed, míg az 1000–1200 m vastag ultrabázitos kőzettestek ezek feletti tektonikai helyzetben találhatóak.

Az allochton fekü összletet szemi-autochton törmelékes, olisztosztromás üledékek kísérik, amelyek a takarómozgásokkal egyidőben képződtek (COBIELLA 1983), majd ezekre fiatalabb autochton vulkanogén és üledékes formációk települtek.

ANN. REP. OF THE GEOLOGICAL INSTITUTE OF HUNGARY, 1992–1993/II: 65–68 (1999)

METHODS AND RESULTS OF THE REGIONAL GEOCHEMICAL SURVEY IN THE GUANTÁNAMO POLYGON, NORTH-EASTERN CUBA

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Manuscript received in 1994.

Keywords: geochemical methods, stream, sediments, sampling, heavy minerals, mineralization, sulphides, gold, chromit, computer programs data processing, statistical methods, north-eastern Cuba

UDC: 550.4:550.84(729.1)550.84:519.688(729.1)

This paper reviews the methods of sampling, data processing and presentation used in the regional geochemical exploration of the Guantánamo Polygon and summarizes the obtained results. Data processing, including the plotting of several maps, was done by computers. Both univariate and multivariate statistical methods were used in order to evaluate the data. As a result, the associations of the path-finder elements and minerals were determined. The multi-element anomalies indicated 19 target areas for more detailed exploration of gold and sulphide ore deposits. Also, the effectiveness of HMC panning in prospecting for chromite deposits was demonstrated.

Introduction

The regional geochemical survey of the Guantánamo Polygon was carried out within the framework of cooperation between the Geological Institute of Hungary and the "Expedición Geológica de Santiago de Cuba" between 1987 and 1990 (GYARMATI et al. 1990). Its main objective was to make ore prediction at a scale of 1:50,000. The area studied occupies 2391 sq.km in north-eastern Cuba. It is characterized by sparse population, subtropical climate and very uneven morphology, large differences in the altitude from 0 m at the shoreline to more than 1100 m. The central part of the area is a highland covered by thick lateritic crust. The drainage system is well developed, with the majority of the streams and rivers running in deep valleys.

Geological setting

Sixty per cent of the territory is composed of ultramafic and mafic rocks of a Jurassic-Cretaceous ophiolite sequence (Fig. 1). The ultramafic rocks are represented largely by serpentinized harzburgite and dunite with wehrlite, lherzolite and pyroxenite, while the mafic rocks by gabbro, microgabbro, gabbro-pegmatite and troctolite. The possible presence of the other members of the ophiolitic sequence (i.e. sheeted dykes, pillow-lavas and pelagic sediments) is still an open question.

Volcanic rocks of a Cretaceous island arc are represented with andesites, dacites, rhyolites and their tuffs. These formations are metamorphosed to greenschist facies in the eastern part of the territory.

These volcanics are situated below the older ophiolitic rocks as a consequence of a Late Cretaceous obduction. Subsequently, near horizontally bedded sedimentary rocks and subordinate acidic tuffs were formed, mainly in the western part of the study area.

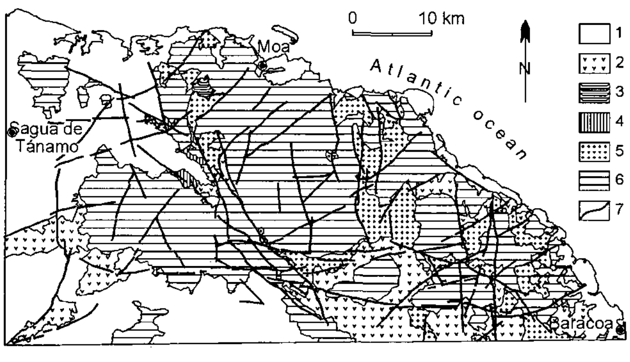

Fig. 1. Geological sketch map of the Guantánamo Polygon (simplified after GYARMATI et al. 1990)

1. Sedimentary rocks, 2. Island-arc volcanics, 3. Pillow lavas (?), 4. Sheeted dikes (?), 5. Mafic cumulates, 6. Ultramafic tectonites and cumulates, 7. Main faults

1. ábra. A guantánamoi kutatási terület vázlatos földtani térképe (Gyarmati et al. 1990 nyomán, egyszerűsítve)

1. Üledékes kőzetek, 2. Szigetív vulkanitok, 3. Párnalávák (?), 4. Párhuzamos telérraj (?), 5. Bázisos kumulátok, 6. Ultrabázisos tömegek (tektonitok és kumulátok), 7. Fő törésvonalak

Table 1 — 1. táblázat

Basic parameters of the sampling
A mintázás alapparaméterei

Sampling method Mintavétel	Number of sample A minták darabszáma	Sampled area (sq.km) A mintázott terület (km^2)	Sampling density (pieces/sq. km) Mintasűrűség (db/km^2)
Stream sediment Mederüledékből	13682	2391	5.5
Soil — Talajból	8727	2391	3.6
Rock — Kőzetből	1577	740	2.1
HMC panning Szérelés	4744	2391	1.9

The most important mineral deposits of the range are the nickeliferous laterite and the refractory chromite that have been mined for a long time. In the areas composed by island arc volcanics, disseminated pyrite and sparse calcopyrite veins were known previously (CABRERA 1971). The geochemical exploration aimed at discovering copper sulphide and, possibly, gold mineralisation.

Sampling and analytical methods

For analytical purposes semi-quantitative optical emission spectroscopy (OES) was available, so a relatively dense sampling was used in order to improve the reliability of the results. Taking into account the morphology and geology of the area, stream sediment sampling was used as the principal method (BEUS, GRIGORIAN 1977). Also, soil metallometry and heavy mineral concentrate (HMC) panning were applied as complementary techniques (Table 1). In some of the promising areas bedrock sampling and/or more detailed sampling were conducted as well. Hydrogeochemical survey, which also plays an important role in similar climatic conditions, was carried out by Cuban colleagues; its results were taken into account in drawing the conclusions for exploration purposes.

The stream sediment, soil and bedrock samples were analyzed by alternating current arc OES for 18 trace elements (i.e. Ti, V, Cr, Mn, Co, Ni, Cu, Zn, Ga, Y, Zr, Mo, Ag, Sn, Ba, La, Yb, Pb). Au content was analyzed by the same OES technique after special sample preparation which included enrichment of the Au using aqua regia.

The HMCs were separated into four fractions. First the magnetic fraction was removed, and the remainder was divided into paramagnetic and nonmagnetic fractions by an electromagnet. The nonmagnetic minerals were separated into heavy and light fractions by using a heavy liquid (bromoform, specific gravity 2.9). The mineral composition was determined using binocular microscopes. However, only the electromagnetic and the heavy fractions were analyzed in detail, while the rest was merely checked for the presence of gold.

Data processing and representation

All the laboratory data were fed into microcomputers and all the sampling locality maps of 1:50,000 scale were digitalized.

The computerized processing of the obtained data was conducted at the "Expedición Geológica de Santiago de Cuba". Both univariate and multivariate statistical methods were used (KOVÁCS et al. 1991). The univariate techniques included the comparison of the empirical and theoretical distribution functions, the estimation of geochemical parameters and the selection of the anomaly thresholds. In most cases the distributions proved to be composite, while in some cases they fitted normal or lognormal functions. Generally it was impossible to determine the anomaly threshold using the histograms (BONDARENKO et al. 1987), so it was defined by the traditional "3 standard deviations" or "3 sigmas" method (BONDARENKO et al. 1985).

Thus, starting from the lognormal model (GRIGORIAN et al. 1983), the geometric mean of the concentrations of the background sample population was considered as the background value (X). In order to represent and evaluate the data, three "intensity classes" or "anomaly levels" were defined. Thus, the $X+3\sigma$ was called the 3rd anomaly level, the $X+2\sigma$ —the 2nd, and the $X+\sigma$— the 1st level. All samples over the 3rd level were considered anomalous. Based on some probability considerations (GRIGORIAN et al. 1983), the samples of the 2nd level were accepted as anomalous only in the case if at least 2 of them were linked; while the 1st level samples were taken as anomalous if there were at least 9 of them clustered together. Otherwise they were not included in the anomalies.

It must be mentioned that, because of the complex composition of the territory, the estimation of the geochemical parameters took into account the geological setting of the sampling site, separating them into 10 groups: ultramafic rocks, gabbro, laterite, volcanics, sedimentary rocks, acidic tuffs etc.

Monoelement point maps at a scale of 1:50,000 were drawn by computer. For the stream sediment sampling, different anomaly levels were indicated by different symbols. Having classified the concentrations, the anomalous dispersion trains were marked by hand. Using the monoelement maps, traditional multielement maps were compiled by superposition. Subsequently, anomalous drainage basins or their anomalous parts could be delineated, on the basis of the multielement dispersion trains.

Similarly, dot maps of distributions of the various trace elements in the soils were drawn by machine and then evaluated by hand, indicating the anomalous areas. In the case of the soil metallometry, only the multielement anomalies were taken into account.

The set of path-finder elements was determined by making use of the analysis of the correlation matrices of the OES data. Owing to this, the predominant influence of trace elements, associated with ultramafic rocks (i.e. Cr, Ni, Co, Mn) was revealed not only in the Quaternary overburden, but in the Tertiary sedimentary rocks as well. In spite of this wide-spread contamination it was concluded that the association of such elements as Cu, Pb, Zn, Ba and Ag indicated reliably shows of copper and polymetallic sulphide mineralisation.

Correlation analysis of the mineral contents revealed two mineral groups in the panned concentrates. One of these is comprised of chromite, hematite and limonite; which was interpreted as a spatial association rather than genetic, conspicuously related to the lateritic cover. So, from this group, only the distribution of the chromite was represented on computer-plotted maps. The other suite consisted of gold, calcopyrite, pyrite, barite, epidote, prehnite etc.; it was assumed to be an association of hydrothermal origin. Accordingly, these minerals were represented on a joint map, by means of colour symbols.

To reinforce the occasional weak anomalies, the Pb·· Zn·· Ba multiplicative index (GRIGORIAN et al. 1983, BONDARENKO et al. 1987) was calculated on the basis of the results from soil sampling. Again, the index was represented on a dot map plotted by computer. It could be concluded that the secondary haloes in this map coincided well with those in the multielement maps, compiled by superposition; moreover some additional anomalies were revealed, due to reinforcement by the multiplication.

Finally, the geochemical prognosis map was compiled, making use of all the previous results. This map shows the primary and secondary haloes, mineralogical and geochemical anomalies in stream sediments, significant hydrogeochemical anomalies and some single anomalous samples. On the basis of these, target areas were indicated for further exploration.

Conclusions

Promising secondary dispersion haloes of Cu, Pb, Zn, Ba and Ag, as well as their anomalous catchment basins are related to the Cretaceous island arc volcanics and, in restricted amounts, to the ultramafic rocks. On the basis of the intensity of the geochemical anomalies, the sulphide mineralisations related to the altered volcanic rocks of the island arc are considered to be the most promising; those associated with the unaltered volcanics may also be important, while the anomalous areas with the same type of mineralisation in the ultramafic environment are interpreted as less productive.

Gold revealed scattered distribution patterns and low values both in HMCs and in the other sample types indicating that the study area on the whole has low potential. Nevertheless, along some tributaries gold-bearing HMC samples are concentrated. The question of the gold potential of the area can only be concluded after checking these catchment areas. The auriferous accumulations, as a rule, associate with the sheared zones of the ultramafic rocks.

This survey demonstrated the effectiveness of the HMC panning in the prospecting for chromite deposits (KOVÁCS 1991). To this end, the concentrations expressed in absolute quantities had to be taken into account, instead of the percentage values. The known ore deposits and shows were indicated by high contents of chromite, proportional to the extent of the mineralisation. Thus, there was a good reason to presume that significant concentrations of chromite, in areas which were previously supposed to be sterile, had to denote unknown ore bodies.

Altogether, the geochemical exploration resulted in delineating 15 target areas for more detailed exploration of copper or polymetallic ore deposits in the Guantánamo Polygon. Also, four target areas were recommended for gold and two for chromite exploration.

However, it should be noted, that this huge data basis requires further processing using other multivariate statistical methods and advanced techniques.

Acknowledgement

I wish to thank P. GYARMATI, ZS. PEREGI (Geological Institute of Hungary), J. CSONGRÁDI (Central Geological Office, Budapest), J. ANDÓ (Eötvös University, Budapest) and G. BRITO (Instituto de Geología y Paleontología, La Habana) for discussions and help during the field work. The assistance of GISELA PÉREZ, ESPERANZA NÚÑEZ, YOLAIDA PÉREZ and MARIA ELENA TAPIA (Expedición Geológica de Santiago de Cuba) in the data processing is gratefully acknowledged.

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A GUANTÁNAMOI KUTATÁSI TERÜLET (ÉSZAKKELET-KUBA) REGIONÁLIS GEOKÉMIAI FELVÉTELEZÉSÉNEK MÓDSZEREI ÉS EREDMÉNYEI

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Tárgyszavak: geokémiai kutatás, mederüledék, mintavétel, nehézásványok, ércesedés, szulfidok, arany, krómit, komputer-program, adatfeldolgozás, statisztikai módszer, Kelet-Kuba

ETO: 550.4:550.84(729.1) 550.84:519.688(729.1)

A cikk áttekinti a guantánamoi kutatási terület geokémiai felvételezése során használt mintavételi, adatfeldolgozási és -megjelenítési eljárásokat. A feldolgozás, a térképrajzolást is beleértve, számítástechnika alkalmazásán alapult. Az adatok értékeléséhez egy- és többváltozós statisztikai módszerek egyaránt felhasználásra kerültek. Ezek segítségével kimutathatók az ércjelző elem- és ásványtársulások. A többelemes anomáliák lehetővé tették 19 — arany-, ill. szulfidércesedésre perspektivikus — továbbkutatásra javasolható terület lehatárolását. A szérelés főként a krómitkutatásban bizonyult hatékonynak.

ANN. REP. OF THE GEOLOGICAL INSTITUTE OF HUNGARY, 1992–1993/II: 69–84 (1999)

ISOTOPE-GEOCHEMICAL STUDIES AND THEIR RESULTS IN THE GEOLOGICAL INVESTIGATIONS OF LAKE BALATON

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Manuscript received in 1993.

Keywords: isotope geochemistry, environmental impact statements, Balaton, Quaternary, radio-carbon age

UDC: 550.4(39:285Balaton) 504.064(439:285Balaton) 550.84(439:285Balaton)

In a complex geological research, several new methods were introduced in order to perform our scheduled tasks. Isotope-geochemical tests have proved to be very efficient, allowing us to have a better understanding of some environmental problems of Lake Balaton including rate of sedimentation, physical properties and underwater motion of mud etc. Results contributed further data on the age of Lake Balaton, and its past climate.

Major results:

(1) Around Lake Balaton, peat development started in the beginning of the Late-glacial (Bölling), and lasted approx. 1500 years. It was most widespread in the Alleröd.

(2) Oxygen isotope ratios measured on the autochtonous carbonate deposits in the lake and on carbonate shells of gastropods are influenced mainly by the evaporation of water. In addition, the latter indirectly depends on the climatic conditions of the particular region, too. The measured values of oxygen isotope ratios allow us to trace the gradual warming-up in the Holocene.

(3) Most of the carbonate in the lake deposits was formed in-situ. Only a negligible amount was transported from the catchment area.

(4) Comparative analysis of $\delta^{18}O$ trends in lake water and the weather conditions shows that, due to intensive evaporation, the oxygen isotope ratio of the water in Lake Balaton is close to that of sea-water and considerably differs from the values for rivers and meteoric water in Hungary. In Hungary, the average $\delta^{18}O$ value is –9.5% for meteoric water, relative to sea-water. In the oxygen isotope ratio of the water of Lake Balaton seasonal changes can be well observed.

(5) A part of the organic matter included in the mud of the lake originates from the recycling of the biological carbon. This process has been going on since the formation of the lake which implies a relative enrichment in $\delta^{13}C$.

(6) Artificial radio-isotope contamination entering the atmosphere since 1950 can be well traced in the mud of the lake. The location of peaks has allowed us to determine the rate of sedimentation. Under undisturbed hydrological conditions, this value ranges from 0.5 cm/year to 1.4 cm/year. The rate of sedimentation changes by time, and in recent years, it has showed a dramatic increase to 2 to 6 cm/year. At some points of Lake Balaton there is underwater sediment transport and accumulation. As shown by our measurements the top 2 to 3 cm of the mud is disturbed by the storms over the lake.

Introduction

Lake Balaton forms an important piece of national heritage for Hungary. It is the largest shallow-water lake in Central Europe. For the last hundred years a great number of specialists of various disciplines have studied it and the surrounding region. The most important milestones of scientific investigations include LÓCZY 1913, SEBESTYÉN 1951, BULLA 1958, BENDEFFY, V. NAGY 1969, BARANYI 1979, MAROSI, SZILÁRD 1981, MIKE 1980a, b, HERODEK, MÁTÉ 1984, 1987, ZÓLYOMI 1952, 1969, 1987, SZESZTAY et al. 1966, MÜLLER 1970, MÜLLER, WAGNER 1978, RÓNAI 1969, SOMLYÓDY 1983. Ongoing investigations continuously add to the ever increasing store of scientific facts. But the lake itself calls our attention again and again to new problems such as mud deposition, eutrophication, the loss of ecological equilibrium, and so on. Each of these represent a challenge for biologist, limnologist and geologist alike. Specialists from the Geological Institute of Hungary have been investigating the lake and its catchment area since 1965, because the geological background (the fossil environment) and the age of the lake is a determining factor for the present day lake, the ecological changes in the water catchment area and the living world of the lake.

An engineering geological survey was carried out in the period from 1966 to 1977 to assess the status of Lake Balaton and its environment, to reduce existing hazards and to reveal potentials for the far future. The area surveyed covered some 780 sq.km of the shore-line zone that is subject to high environmental pressure (RAINCSÁKNÉ, CSERNY 1984, CSERNY 1984). The initial survey was followed by two projects running concurrently. Environmental geological surveying was extended to the whole of the tourist region to cover 5200 sq.km. The second project was the detailed investigation of the sediments in the lake bed. These research programmes resulted in the compilation of an engineering geological map series at scales of 1:10,000–1:100,000 (CSERNY 1990). The compiled map sheets are already widely used to solve both regional and local problems of utilisation, environment management, agriculture and water management.

The investigation of Lake Balaton is of great importance due to the intensive mud deposition and eutrophication of the lake itself. Although the ageing and filling-up of lakes is a natural process, it may be accelerated by some environmental (particularly, human) influences.

The aim of the environmental geological investigations which started in 1981 was to study the present sedimentological conditions and the diagenesis of shallow-water carbonate sediments. This environmental geological topic which started as a pilot study of techniques also aimed, from 1986, at a better understanding of the history of development of the lake and the changes in its ecological conditions. Over 370 km of seismic lines were shot and a total of 33 boreholes were drilled into the lake bed. The boreholes have allowed us to compile the mud thickness map. Seismic data were used for the compilation of the structural map of the basement of Lake Balaton at 1:500,000 scale. Samples from two-thirds of the boreholes have been analysed in the laboratory in a wide range of tests which included sedimentological, soil-physical, mineralogical, petrological, geochemical, palaeontological investigations (M. FARAGÓ 1982, BODOR 1987, BRUKNER-WEIN 1988, CSERNY 1987, 1990, CSERNY, CORRADA 1989, CSERNY et al. 1991).

The aim of this paper is to give a brief description of the isotope geochemical investigations and the relevance of geochemical results to geological problem solving.

G. MÜLLER and F. WAGNER (1978) were the first to use isotope geochemical techniques in the study of Lake Balaton, and gave a reconstruction of climate on the basis of results of mineralogical, geochemical and isotope geochemical study of Quaternary lacustrine sediments. The autochtonous carbonate deposit of the fine fraction of the samples was tested for ^{18}O isotope ratio. The calcite lattice of some beds was found to have increased $MgCO_3$ concentrations which represents unordered proto-dolomite. This is has high Sr concentration and positive ^{18}O value. As expected in the case of an intensive evaporation the ^{18}O value occurs in larger proportion in water and this may lead to an isotope enrichment in the carbonate deposits as well. Two well defined Mg maxima were observed in the borehole profile. Comparison with the results of palynological study by B. ZÓLYOMI (1952, 1987) indicated that these sediments were deposited in a shallow water, under dry and warm climatic conditions.

E. HERTELENDI performed radio-carbon dating in 1987 on samples from a peat deposit found in the lower part of the section by boreholes that have been drilled into the lake bed. Peat samples from the lower section from four boreholes were subject to pollen analysis by MS. NAGY. The results only show an approximate correlation, that is, the results of pollen analysis indicate a Pinus–Betula vegetation phase (the very beginning of Holocene time), whereas the radio-carbon dating indicates an age of 10,500 to 12,000 yrs BP, that is, Late-glacial (Pleistocene) Alleröd (CSERNY, CORRADA 1989).

Starting in 1981 our investigations continued earlier isotope geochemical studies and added new techniques to extend the range of problems answered.

A contribution to the isotope geochemistry

^{14}C dating was performed on peat, on samples from 7 additional boreholes, in order to date the lacustrine sediments. For paleo-climatological reconstruction, ^{13}C and ^{18}O ratios were also measured in water samples of Lake Balaton, the autochtonous lacustrine carbonate mud, molluscan shells collected from the sediment, and on samples from the carbonate rocks and carbonate-bearing unconsolidated deposits in the catchment area of Lake Balaton. In addition, ^{137}Cs and ^{134}Cs was also determined in order to estimate the rate of underwater reworking of lacustrine deposits, including the rate of sedimentation. Finally, in-situ gamma-gamma logging was carried out in the Keszthely Bay (Fig. 1, around Tó–31) using isotope source to help with plans of mud dredging.

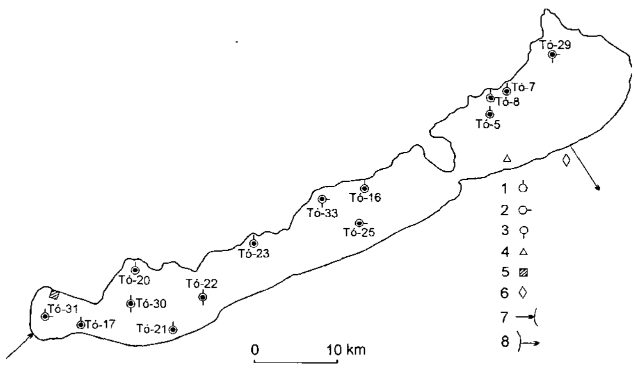


***Fig. 1.* Layout of boreholes and sampling sites**
1. Peat-cutting borehole including radio-carbon dating, 2. Borehole, with $\delta^{13}C$ and $\delta^{18}O$ testings, 3. Borehole, with ^{137}Cs isotope testing, 4. Water sampling site, for regular ^{18}O testing, 5. Site of experimental dredging, 6. Hydro-meteorological station, 7. Zala river (main input), 8. Sió channel (only output)

***1. ábra.* A fúrások és a mintavételezési pontok helyszínrajza**
1. Tőzeget harántolt fúrás, radiokarbon kormeghatározással, 2. Fúrás, $\delta^{13}C$ és $\delta^{18}O$ izotóparány vizsgálatokkal, 3. Fúrás, ^{137}Cs izotóp vizsgálattal, 4. Vízminta vételi hely, rendszeres $\delta^{18}O$ izotóp vizsgálattal, 5. A kísérleti kotrás helye, 6. Hidro-meteorológiai állomás, 7. Zala (a fő vízutánpótlás), 8. Sió (az egyetlen kifolyás)

Radio-carbon dating of peat samples from Lake Balaton

A brief summary of the method

In the upper half of the atmosphere surrounding the Earth a considerable amount of free neutrons are generated by cosmic rays (e.g. LIBBY 1967). In response to these neutrons, carbon isotope of mass number 14 can be generated in the atmosphere as an end product of a chain of nuclear reactions. LINGENFELTER (1963) relying upon data obtained by others has proved that the dominant reaction is ^{14}N (n,p) ^{14}C, whereas the rest of reactions play no significant role. The produced ^{14}C will decompose into ^{14}N through beta emission with a half-life of 5730±40 yrs (GODWIN 1962) [E_{max} = 60 keV]. In the atmosphere, radiocarbon is rapidly oxidised into carbon dioxide, thereby allowing for continuous tracing of carbon dioxide in the atmosphere. ^{14}C enters into the food chain by photosynthesis and will be present in the biological carbon of the living world. The intensity of cosmic radiation has been nearly constant for a long time. The half-life of ^{14}C, 5730 years, can also be considered as a short period geologically. Cosmogenic ^{14}C is thus in radioactive equilibrium on the Earth. The isotope ratio under equilibrium condition is as follows: $^{14}C/^{12}C = 1.17\times10^{-12}$. In metabolic processes radio-carbon is continuously taken up and released by living creatures. The biological half-period typical of living creatures —that is, a period over which half the organic compounds forming a living creature is exchanged— is a couple of years, that is, a brief period, as compared to the half-period of radio-carbon. Thus, the specific radioactivity of biological carbon in living creatures always corresponds to the specific radio-carbon activity of atmosphere. When metabolism stops no further ^{14}C integration takes place. Therefore the ^{14}C concentration in biological carbon will exponentially decrease corresponding to the half-period.

Knowing the specific radioactivity (A_0 — initial activity) of carbon content of the living matter during the metabolism, then measuring the specific activity after the metabolism has stopped (A — present activity), and also knowing the decay constant (T), we can determine the time when the processes associated with life stopped, that is, the age of a particular sample (t) according to the following formula:

$$A = A_0 \times e^{-t}.$$

This is the principle of radio-carbon dating.

The specific radio-carbon activity of biological carbon of living vegetation slightly differs from the specific radio-carbon activity of the atmospheric carbon. This difference is due to isotope fractionation during photosynthesis, and its measure varies from plant to plant. The error in radio-carbon dating caused by the isotope fractionation can be corrected by means of mass spectrometry measurement of the $\delta^{13}C$ value, since on the basis of thermodynamic considerations, the enrichment, or reduction of carbon isotope of mass number 14 is twice as that of isotope of mass number 13.

The radio-carbon activity corrected in regard to isotope fractionation (A_{korr}) can be calculated from the measured value of activity (A) according to the following formula:

$$A_{korr} = A[1-2\times10^{-3}(25+\delta^{13}C)]$$

where $\delta^{13}C$ is the amount of carbon 13 in the gas used to measure the activity. Using this correction, the $\delta_{PDB}{}^{13}C$ value of each sample is normalised, by convention, to a value of −25 % which is the average value for vegetation.

For radio-carbon dating, the concept of "conventional radio-carbon" age is of prime importance. The conventional radio-carbon age is calculated under the following conditions specified on an international basis:

— LIBBY's original value of half-period (5568 yrs) is used as half-period.

— It is assumed that the atmospheric ^{14}C concentration has been constant.

— Each activity measurement shall be related, according to the law of radioactive decomposition, to 1950 BP (before present). Thus, each measurement will be independent of the actual date and time it was performed.

— "Modern equivalent": oxalic acid supplied by the National Bureau of Standards (Washington, D.C.) is used as a standard. The 95% of NBS oxalic acid, normalised to PDB13 = −19%, related to 1950, gives the natural activity level of ^{14}C. This activity matches the specific radio-carbon activity of carbon content of annual rings developed in trees in the year 1890.

— The carbon isotope ratio of each sample shall be normalised to a value of $\delta_{PDB}{}^{13}C = -25\%$.

There are historical reasons for the usage of conventional radio-carbon age (referred to as BP). In 1951 when the first radio-carbon measurements were performed, the half-period was considered as $T_{1/2}$=5568 yrs, based on the best measurements of that time. Using this half-period, a great number of data from radio-carbon dating were supplied by laboratories. However, the more precise measurements performed later indicated a half-period of 5730±40 yrs (GODWIN 1962). In addition, atmospheric ^{14}C concentration was assumed to be constant. This assumption is now disproved. However, the BP age has been maintained by the community involved in radiocarbon techniques. Thus, data from radio-carbon dating can be compared with each other. Should you wish to convert a BP age to calendar years, on the basis of our present knowledge, you should perform the following operations:

1. Use various calibration tables, or programs to calculate the calendar year age, for the time range in which the actual value of the atmospheric ^{14}C activity is known, on the basis of internationally accepted measurements (for the time being, this period ranges from 1950 AD to 5210 BC);

2. Should BP relate to a time for which the atmospheric ^{14}C concentration is not known precisely, increase the BP age by

$$\frac{100\times(5730-5568)}{5568} = 2.9\%.$$

Results from the investigations

The ^{14}C dating method has played a very important role in dating the peat strata penetrated by boreholes drilled into the bed of Lake Balaton. Our starting point was that peat had been identified in a third of the boreholes, between the lithologically uniform, unconsolidated lacustrine lime mud and the compact, dominantly pelitic, Upper Pannonian deposits forming the lake basement (Fig. 1). The peat bed with a thickness of 0.2 to 1.2 m was, generally, the oldest Quaternary formation here after an intensive erosional and deflational denudation taking place in the Pleistocene. The peat bed to developed under favourable climatic conditions in an area inundated by water. Samples taken from the peat at 10 to 20 cm intervals were subjected to radio-carbon dating.

Radio-carbon dating of peat samples allows us to draw several important conclusions: In the Balaton area the peat development started in the Late-glacial, during the Bölling warming-up period following the Oldest Dryas. This process, however, lasted a long time in the area of the lake and was the most widespread during the Alleröd following the Older Dryas. The youngest peat was formed during the Younger Dryas. As shown by the radio-carbon dating of the thickest (1.2 m thick) peat bed penetrated by the boreholes, the peat development continued for a period of 1200 to 1500 yrs.

Table 1 — 1. táblázat

Radio-carbon age of samples penetrated by boreholes drilled into Lake Balaton
Fúrási minták radiokarbon kora

deb-No.*	borehole No. and depth interval (in m)		^{13}C	BP age (yrs)
deb-576	Tó–5	2.03–2.05	–27.85	11250±170
deb-583	Tó–7	1.85–1.90	–28.62	12080±160
deb-584	Tó–8	2.18–2.22	–29.30	11500±170
deb-563	Tó–16	3.80–3.85	–28.68	10490±200
deb-1766	Tó–17	3.00–3.10	–29.28	10140±300
deb-1800	Tó–17	3.10–3.20	–29.19	10350±300
deb-1816	Tó–17	3.20–3.30	–29.00	10590±300
deb-1824	Tó–17	3.30–3.40	–28.10	10800±300
deb-1806	Tó–17	3.40–3.50	–27.96	11370±300
deb-2246	Tó–20	3.00–3.08	–29.56	11460±300
deb-2247	Tó–20	3.08–3.16	–30.95	11680±300
deb-2239	Tó–20	3.16–3.24	–30.83	11660±300
deb-2250	Tó–20	3.24–3.37	–29.15	11620±300
deb-1628	Tó–21	1.80–2.00	–29.14	11110±200
deb-1631	Tó–21	2.75–2.83	–29.74	12280±200
deb-1634	Tó–21	2.83–2.93	–22.60	12340±200
deb-1809	Tó–22	2.80–3.10	–29.18	10980±300
deb-1817	Tó–22	3.30–3.40	–28.67	11560±300
deb-1825	Tó–22	3.40–3.50	–28.93	11950±300
deb-1833	Tó–22	3.50–3.60	–29.00	12490±300
deb-1627	Tó–23	4.75–4.88	–30.22	11860±200
deb-1626	Tó–23	4.88–5.00	–29.49	11800±200
deb-1629	Tó–23	5.00–5.12	–28.65	12060±200
deb-1633	Tó–23	5.12–5.24	–30.53	12020±200
deb-1801	Tó–30	3.90–4.00	–29.28	10960±300
deb-1632	Tó–31	3.40–3.60	–29.56	12210±300
deb-1624	Tó–31	3.60–3.80	–31.79	12490±300
deb-1623	Tó–31	3.80–3.94	–30.24	12020±300

*(deb — refers to the international standard No. of the particular sample. A szám az egyes minták nemzetközi standard száma.)

Measuring stable isotope ratios in samples from the deposits and water of Lake Balaton

A brief description of the method

For each element, the chemical properties are determined by the electrons found on its outer electron orbit, whereas its macroscopic physical properties are determined by the nucleus. Thus, in the case of isotopes, since the number of electrons is the same, no essential difference in chemical properties can be expected. However, slight differences still exist. The effect of differences in the physical and chemical properties of the isotopes of an element, on a process is called isotope effect that is due to a relative mass difference. Should the isotope ratio of an element participating in a chemical, biological, or physical process change in a particular component or phase during the particular process, then isotope fractionation is taking place. Its degree is characterised with the fractionation factor.

In isotope fractionation processes taking place in the nature, the isotope ratio is generally subject to minor changes only, therefore, the absolute isotope ratio measurements do not allow us to follow the processes. In the practice of measurements, the isotope ratio related to one standard and expressed in terms of ‰, referred to as delta value is used according to the following formula:

$$\delta = \frac{R_{minta} - R_{standard}}{R_{standard}} \times 1000 \qquad (1)$$

where

R_{minta} = the isotope ratio for the particular sample,

$R_{standard}$ = the isotope ratio for an international standard.

Table 2 shows the internationally accepted standards applied in the isotope ratio measurements of five elements (S, C, H, O, N) that are most important in isotope geology.

Table 2 — 2. táblázat

Standards used in the isotope ratio measurements of S, C, H, O and N
Viszonyítási alapok a kén, szén, hidrogén, oxigén és nitrogén izotóparány mérésekben

Element	Name of the standard	Standard marked
H, O	Standard Mean Ocean Water (H_2O)	SMOW
C, O	*Belemnitella americana* from the PeeDee Formation ($CaCO_3$)	PDB
S	Troilite from the Canyon Diablo iron meteorite (FeS)	CD
N	Atmospheric nitrogen	

In addition to the above standards, a great number of other standards are also used (GONFIANTINI 1983, FRIEDMAN, O'NEIL 1977).

Results from the investigations

Using a mass spectrometer developed by ATOMKI and designed to measure isotope ratio (HERTELENDI et al. 1986), measurements were made on the following types of samples in order to experimentally determine the $\delta^{13}C$ and/or $\delta^{18}O$ isotope ratios:

— Carbonates in samples from the Quaternary lime mud penetrated by boreholes Tó–25 and Tó–31.

— The pore water distilled from the samples of the aforesaid boreholes.

— The organic matter of core samples.

— Samples taken from the water of Lake Balaton once a week, over a period of a year and a half.

— Carbonate rocks and carbonate-bearing unconsolidated deposits collected from the catchment area of Lake Balaton (Fig. 1).

With regard to geology, the aim of the experimental measurements was to contribute to the palaeo-climatological reconstruction of Lake Balaton and its environs by revealing and explaining the changes in stable-isotope ratios.

The following additional explanatory notes are added to the results of measurements:

1. The two boreholes drilled into Lake Balaton were selected so that the deposits should dominantly consist of autochtonous carbonates. The boreholes were sampled at every 10 cm, and the results of measurements were plotted as logs (Figs. 2, 3), and as X-Y plot (Fig. 4). The isotope ratios change with depth the same way in both boreholes. Borehole Tó–31 drilled in the Keszthely Bay contains less carbonate than borehole Tó–25 which clearly proves that in addition to the autochtonous carbonates, an enormous amount of allochtonous material has also accumulated in the bay. This intensive mud deposition is also the reason why the variation in isotope ratio vs. depth (thus, vs. time) is less visible in borehole Tó–31 than in borehole Tó–25. The isotope logs, especially the $\delta^{18}O$ log, with their more positive values visible as a function of depth, well reflect the dry climatic stages (where the evaporation was intensive) of the past. Good correlation has been observed between $\delta^{13}C$ and $\delta^{18}O$ isotope ratios measured on samples from Quaternary deposits.

2. A cross-plot of the measurements of pore water distilled from the core samples and the $\delta^{18}O$ values of carbonates (Fig. 5) shows little correlation. The two data sets are expected to be different because of the mixed origin of pore waters: some of it is syngenetic with the sediment while part of it may originate from deeper, older sediments. The compaction of sediments of high water content expels the pore water which flows upward. Such mixing is of little consequence for sequences of a few ten or hundred metres, where, although the transition between the measured values is not sharp, the trends are clearly visible. In our particular case, the sediment of the Balaton is only a few metres thick, so the vertical scale of mixing is comparable to the sampling interval used (10 cm) and so the correlation shown in Fig. 5 can be considered to be meaningful.

3. Gastropods were collected from several boreholes. The shells of *Lythogliphus naticoides* occur at every level, at some levels en mass. This species was selected for analysis by P. SÜMEGI. We assumed that if the $\delta^{18}O$ and $\delta^{13}C$ isotope ratios of the calcareous test vary in the same way as the isotope ratios of the total carbonate of the deposits, it would mean that most of the carbonate is autochtonous. Then the allochtonous carbonate content of the deposit, transported from the water catchment area is negligible. Based on the isotope ratio of Lythogliphus shell, the sections were subdivided into three levels. The middle one, representing the Early Holocene, was only level rich enough in carbonate shells to ensure that the measurements can be reliably evaluated. This is the level that contains gastropod shells en mass. Here we observed the isotope ratios slowly drifting in the positive direction (Fig. 6). This indicates the increasing evaporation of the lake due to climatic warming and a decrease in precipitation.

4. $\delta^{13}C$ was measured in the organic matter in samples taken from borehole Tó–31 at 10 cm intervals. With simi-

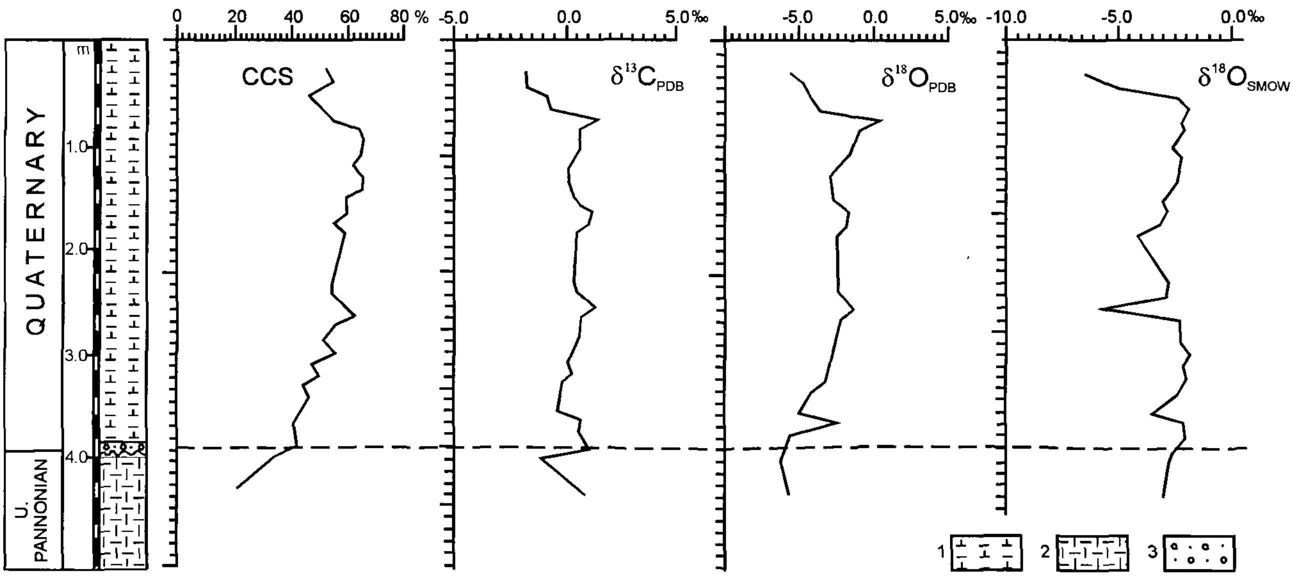


Fig. 2. $\delta^{13}C$ and $\delta^{18}O$ values, vs depth, measured in samples from borehole Tó–25

1. Clayey carbonate mud, 2. Clayey silt, 3. Pebbly, silty sand, CCS. Carbonate content of the sediment, PDB. Measured in carbonate, SMOW. Measured in interstitial water

2. ábra. A Tó–25 fúrás mintáiban mért $\delta^{13}C$ és $\delta^{18}O$ izotóparányok, a mélység függvényében

1. Agyagos mésziszap, 2. Agyagos kőzetliszt, 3. Kavicsos, kőzetlisztes homok, CCS. Karbonáttartalom, PDB. Karbonátban mért, SMOW. Pórusvízben mért

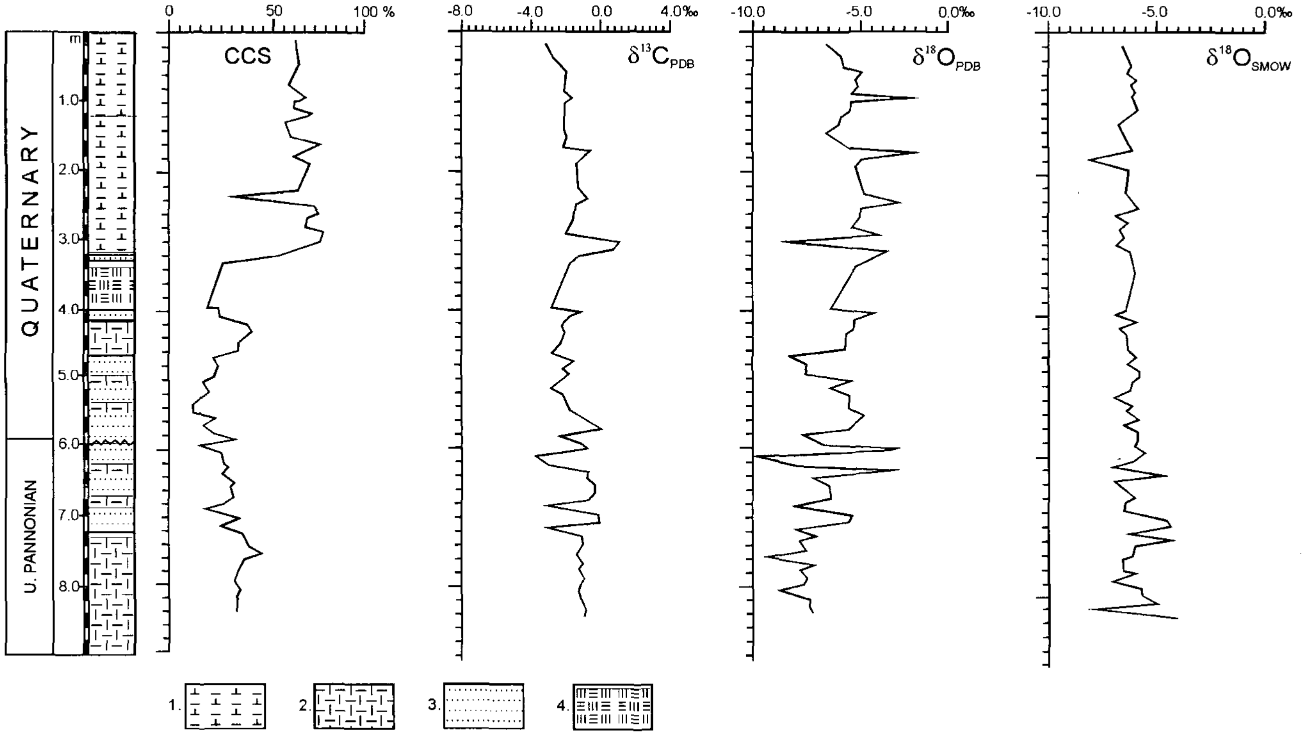


Fig. 3. ^{13}C and ^{18}O values, vs depth, measured in samples from borehole Tó–31
3. Sand, 4. Peat. For the others see Fig. 2

3. ábra. A Tó–31 fúrás mintáiban mért δ^{13}C és δ^{18}O izotóparányok, a mélység függvényében
3. Homok, 4. Tőzeg, a többit l. a 2. ábránál

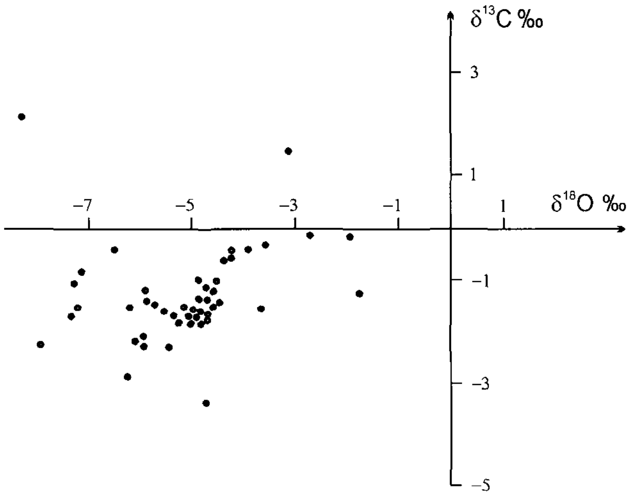


Fig. 4. Relationship between δ^{13}C and δ^{18}O values in borehole Tó–31

4. ábra. Összefüggés a δ^{13}C és δ^{18}O izotóparányok között, a Tó–31 fúrásban

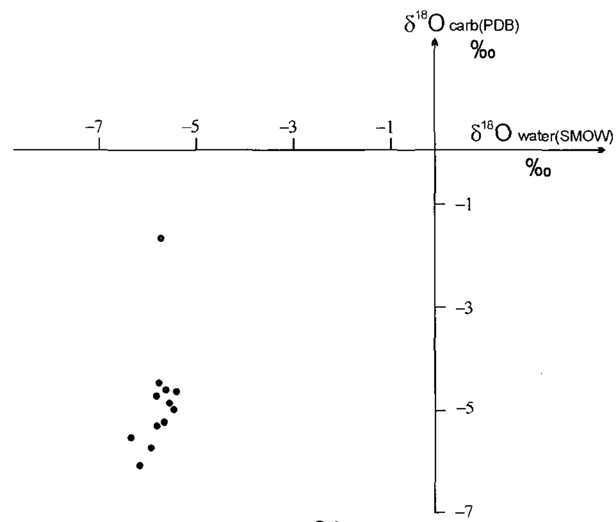


Fig. 5. Relationship between δ^{18}O values of carbonate and interstitial water in borehole Tó–25

5. ábra. Összefüggés a karbonát és a pórusvíz δ^{18}O arányai között a Tó–25 fúrásban

lar reasoning to the above we assumed that the change in δ^{13}C isotope ratio of the organic matter accumulated together with the deposit showed a trend that was similar to the corresponding values of the total carbonate of the deposit and the calcareous test of the gastropods. The results were plotted by depth (Fig. 7). This clearly shows that a certain trend can be observed in the δ^{13}C isotope values of the organic matter. For peat beds, and beds with a high organic matter content, the δ^{13}C values are much more negative. The reason for this lies in the increased amount of carbon atoms present.

The δ^{13}C values are more positive for the Upper Pannonian basement formations than for the Quaternary deposits. The jump in the values indicates the position of the unconformity boundary.

5. From July 1991 to January 1992 the water in Lake Balaton was sampled once a week, at Balatonszéplak, approx. 1 km offshore. The aim of the series of measure-

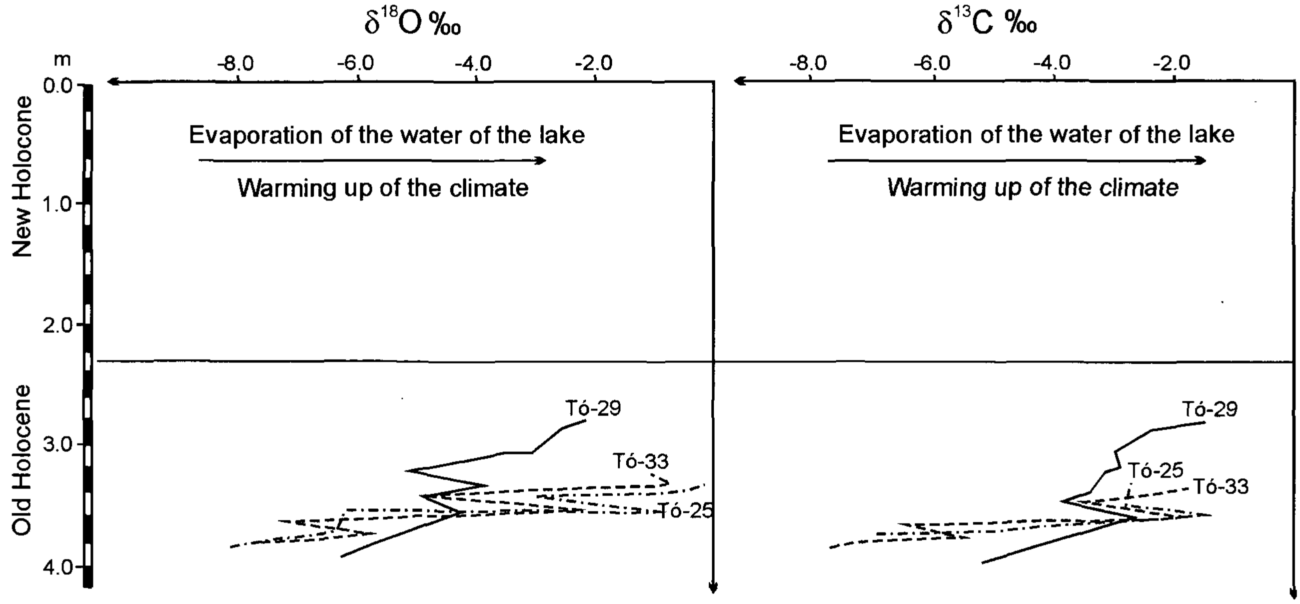


Fig. 6. The variation of $\delta^{13}C$ and $\delta^{18}O$ values, vs depth, in the carbonate shells of *Lythogliphus naticoides* (Gastropoda)

6. ábra. A $\delta^{13}C$ és $\delta^{18}O$ arányok változása a *Lythogliphus naticoides* (Gastropoda) karbonát vázában, a mélység függvényében

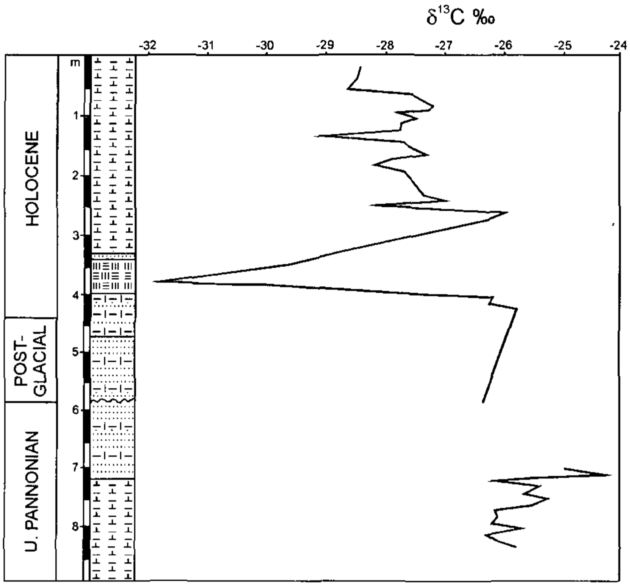


Fig. 7. The variation of $\delta^{13}C$ value, vs depth, in the organic matter taken from borehole Tó–31 (For legend see Figs. 2 and 3)

7. ábra. A szerves anyagban mért $\delta^{13}C$ izotóp arány változása a mélység függvényében, a Tó–31 fúrásban (A litológiai jelek mint a 2. és a 3. ábrán)

ment was to establish the average $\delta^{18}O$ value of water in Lake Balaton, and the magnitude of its seasonal variation, and to quantify the influence of temperature and precipitation (the water level) on the trend of oxygen isotope ratio of the water. Knowing the values of $\delta^{18}O$ and temperature for present day lake water and the $\delta^{13}C$ and $\delta^{18}O$ values of the recently formed carbonates would allow us to obtain a relationship between the temperature and the isotope ratios of carbonates. This relationship can then be projected to earlier stages of the lake. Results from the measurements were plotted in a diagram (Fig. 8). The $\delta^{18}O$ value varied in the range from 0 to –2‰ in the water samples and, as shown by a polynomial fit to the curve, the amplitude of the variation was between 0.9 and 1.0‰. The most positive value was reached at the end of the summer, and the most negative value in the beginning of spring. This can be excellently correlated with the weather conditions prevailing in the environs of the lake. In summer the intensive evaporation from the lake surface (approx. 1 mm/day) and the great deficiency in precipitation causes an enrichment of the lake water by heavy oxygen isotope. Thus the measured $\delta^{18}O$ value becomes more positive. The $\delta^{18}O$ value varies from –4 to –12‰ in precipitation and rivers in Hungary. The thick ice layer covering the lake in wintertime further reduces evaporation. It is easy to understand the more negative $\delta^{18}O$ values measured during the early spring.

We have failed to find any correlation between the $\delta^{18}O$ values measured in water and the carbonates in the top mud layer. This may be because seasonal changes take place too rapidly, and on the other hand, the sediment in the lake is disturbed by storms several times a year.

6. The information content of isotope ratio values measured on the carbonates of the mud in the lake is greatly influenced by the fact if the carbonates are not formed in-situ but are transported there from the catchment area. To eliminate the effect of allochtonous carbonates it would be advisable to select, generally, a pilot area where the geological background is free of carbonate. This was, however, impossible in the case of Lake Balaton. Instead, we sampled the most widespread carbonate rocks and carbonate-bearing sediments in the catchment area and tested them for isotope ratio (Table 3). This supplied $\delta^{13}C$ and $\delta^{18}O$ values for the allochtonous carbonates, and helped to clarify their possible proportion in the Balaton mud. The

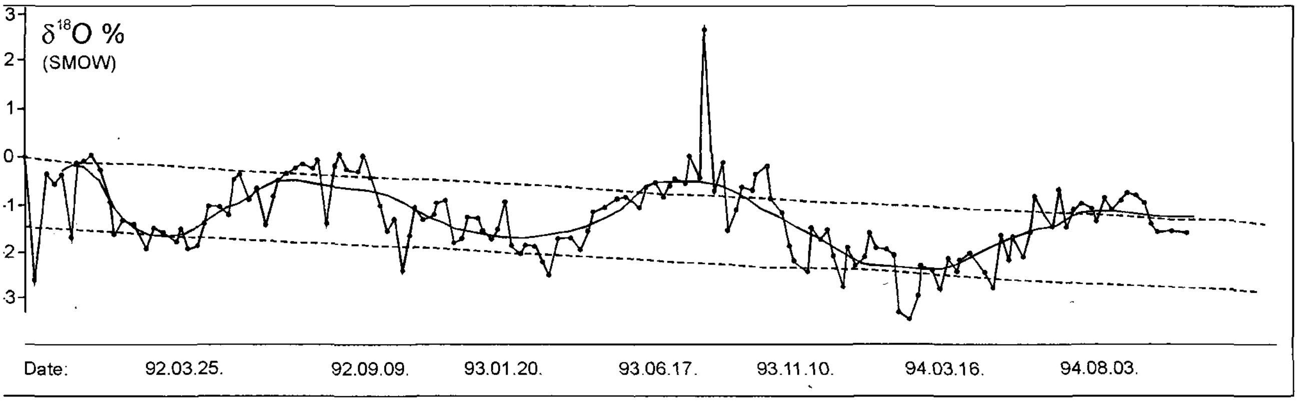


Fig. 8. Temporal changes in the ratio of oxygene isotopes in the water of Lake Balaton (water sampling at Balatonszéplak village)

8. ábra. A Balaton vize oxigénizotóp arányának változása az idő függvényében (felszíni minta, Balatonszéplaknál)

measured values shown in Fig. 9 allow us to distinguish carbonates of different origin: the $\delta^{13}C$ and $\delta^{18}O$ values of potentially transported carbonates are separated from that of the Quaternary lacustrine deposits by the value of the $\delta^{13}C = f(\delta^{18}O)$ discriminant function.

Testing the samples from boreholes drilled into lake Balaton for artificial and natural isotopes

A brief description of the method applied

Like stable isotope ratios, the distribution of radioactive isotopes of artificial or natural origin in a particular geological environment provides evidence of past and present transport and geochemical alteration processes.

^{137}Cs is one of the most important artificial radioactive isotopes in terms of quantity and frequency of occurrence. Generated in atmospheric nuclear explosions and nuclear plant accidents, it is present on the northern and southern hemisphere alike, as an anthropogenic isotope contaminant. Its half-period (30 yrs) is a brief period on a geological scale. Thus, it is only useful in the study of fast, transient surface processes (for instance, sedimentation in rivers and lakes).

During the Chernobyl nuclear accident, a 1:2 mixture of ^{134}Cs and ^{137}Cs isotopes was released into the environment. For a couple of years following the accident, it was possible to estimate the ratio of "new" ^{137}Cs freshly released from Chernobyl and "old" ^{137}Cs originating from earlier atmospheric nuclear weapon tests.

Concurrently with the determination of the artificial isotope ratios, a few natural radioactive isotopes were also measured. The most important among these are ^{40}K, and the isotopes of the three radioactive decomposition series (uranium, thorium, actinium).

Results from our investigations

The measurements of natural and artificial isotopes were performed, on a commission from the Geological Institute of Hungary, by the Department of Radiology at the Institute for Food Control. The uppermost, 50 to 80 cm thick mud layer in four boreholes were sampled, uniformly, at every 2 cm. The aim of the bed-by-bed radiological test of the samples was to determine the activity-concentration of the ^{134}Cs and ^{137}Cs isotopes and the gamma emitting isotopes in the particular mud bed.

The results from the measurements were expected to answer the following questions:

(1) Can we detect maxima of atmospheric fall-out caused by nuclear tests and the Chernobyl accident in the mud in Lake Balaton?

Table 3 — 3. táblázat

Site/Sample+ Lelőhely/minta+	$\delta^{13}C$	$\delta^{18}O$
Csopak/1	+3.76±0.08	+1.17±0.06
Csopak/2	+2.93±0.06	–4.02±0.07
Aszófő/3	+0.55±0.07	–3.62±0.07
Pécsely/4	+2.22±0.02	–3.59±0.05
Csopak/5	–0.63±0.05	–1.88±0.12
Csopak/6	+2.15±0.04	–3.36±0.09
Balatonfüred/7	+0.64±0.05	–7.09±0.09
Barnag/8	+0.15±0.08	–3.57±0.07
Barnag/9	–6.22±0.08	–6.99±0.06
Csopak/10	+2.66±0.08	–2.67±0.05
Kővágóörs/11	no carbonates — nincs gáz	
Balatonalmádi/12	–0.11±0.06	–4.15±0.08
Balatonboglár/13	–5.23±0.06	–7.62±0.09
Zánka/14	–3.23±0.05	–5.34±0.07
Révfülöp/15	–6.73±0.05	–10.58±0.09
Tihany/16	–1.84±0.06	–7.05±0.08
Cserszegtomaj/17	no carbonates — nincs gáz	
Tihany 1/18	–0.08±0.07	–7.14±0.10
Tihany 2/19	no carbonates — nincs gáz	
Tihany 3/20	–0.72±0.07	–6.22±0.08
Rádpuszta 1/21	–5.74±0.05	–7.79±0.08
Rádpuszta 1a/22	–3.39±0.05	–7.08±0.06
Rádpuszta 2/23	–10.98±0.04	–10.15±0.04
Rádpuszta 3/24	no carbonates — nincs gáz	
Rádpuszta 4/25	–4.93±0.08	–7.95±0.10
Rádpuszta 5/26	–4.31±0.07	–6.91±0.12
Rádpuszta 6/27	–0.34±0.09	–6.40±0.09
Balatonszemes/28++	–2.07±0.07	–6.44±0.03
Zamárdi 1/29+++	no carbonates — nincs gáz	
Zamárdi 2/30	–5.03±0.05	–7.80±0.09

+ For age and rock See Fig. 9. — Kor és kőzet a 9. ábránál.
++ Faced the camping site — A kempinggel szemközt.
+++ U. Pleistocene loess originated soil.

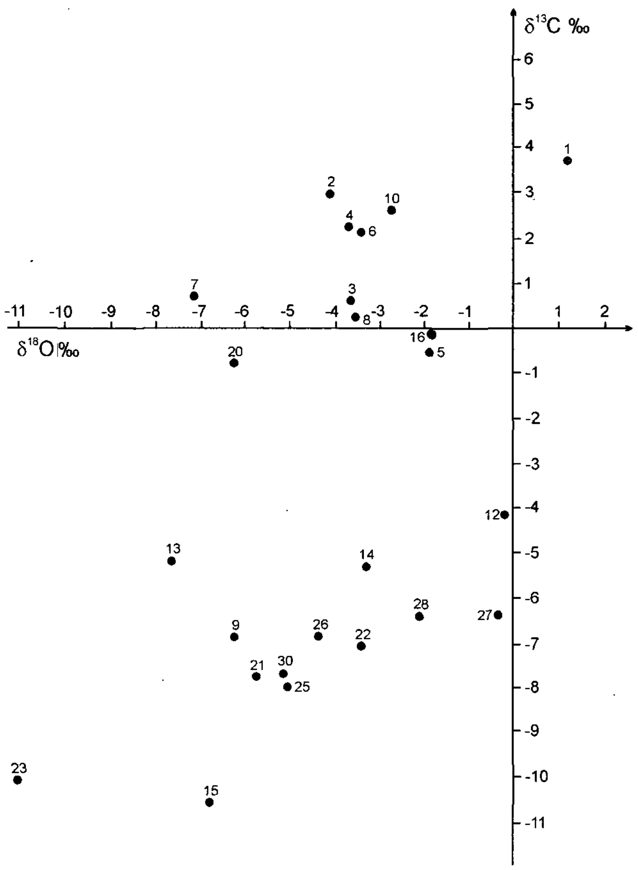


Fig. 9. $\delta^{13}C$ and $\delta^{18}O$ values of carbonate rocks and unconsolidated deposits of various genetics collected in the catchment area of Lake Balaton (cp. table 3)

1, 3, 7, 9. Dolomite, 2, 6, 10, 14. Limestone, 4, 5, 8. Bituminous limestone, 12, 18. Sandstone, 13, 16. Basalt tuff, 15. Phyllite, 19. Clayey aleurite, 20. Claymarl, 21, 22. Loess; 15. Silurian, 12. U. Permian, 7. L. Triassic, 3, 8, 9. M. Triassic, 1, 2, 4, 5, 6, 10, 11. U. Triassic, 14. Sarmatian, 16 to 20, 23, 25, 26, 27. U. Pannonian, 21, 22, 28, 30. U. Pleistocene. Absent figures (11, 17, 19, 24 and 29) refer to "no carbonates" samples listed in the table 3

9. ábra. $\delta^{13}C$ és $\delta^{18}O$ izotóp arányok a Balaton vízgyűjtőjén szedett, különböző genetikájú és korú karbonátos kőzetekben és laza üledékekben (Vö. a 3. táblázattal)

1, 3, 7, 9. Dolomit, 2, 6, 10, 14. Mészkő, 4, 5, 8. Bitumenes mészkő, 12, 18. Homokkő, 13, 16. Bazalttufa, 15. Filllit, 19. Agyagos aleurit, 20. Agyagmárga, 21–22. Lösz. A hiányzó számok a gáz (tehát a karbonát) hiányára utalnak

(2) If so, what sedimentation rate do the measurements imply in the lake?

(3) Is the rate of sedimentation uniform all throughout Lake Balaton?

(4) What thickness of the mud in the lake is disturbed storms?

(5) Is there any underwater sediment transport in the lake?

To answer these questions four boreholes were selected among those drilled in 1989. The selection was also helped by Landsat satellite image of the lake. The satellite image clearly showed the areas where the amount sus-

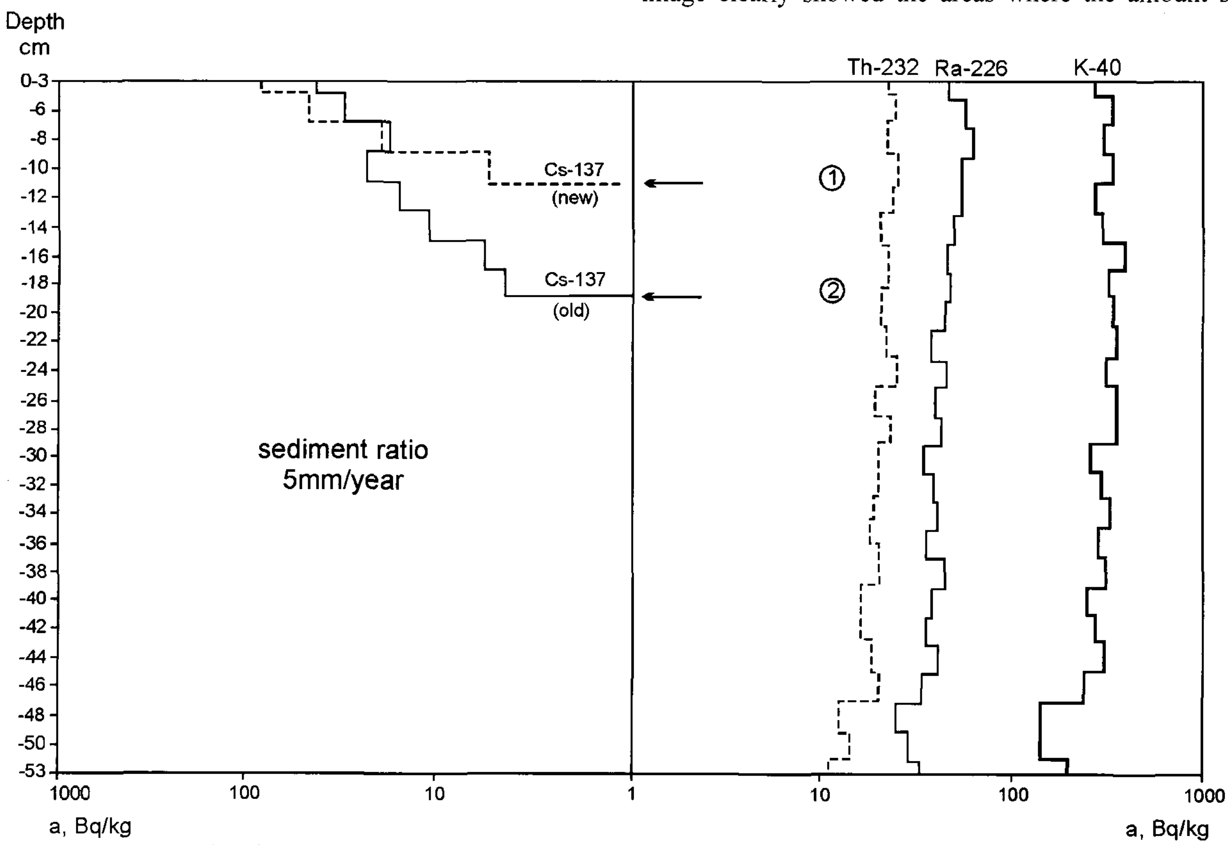


Fig. 10. The variation of natural and artificial isotopes by depth in borehole Tó–22

1. Reactor accident in Chernobyl, 2. Beginning of the nuclear experiments

10. ábra. A Tó–22 fúrás mintáinak radioaktivitása

1. A csernobili atomreaktor baleset, 2. A légköri atomrobbantások kezdete

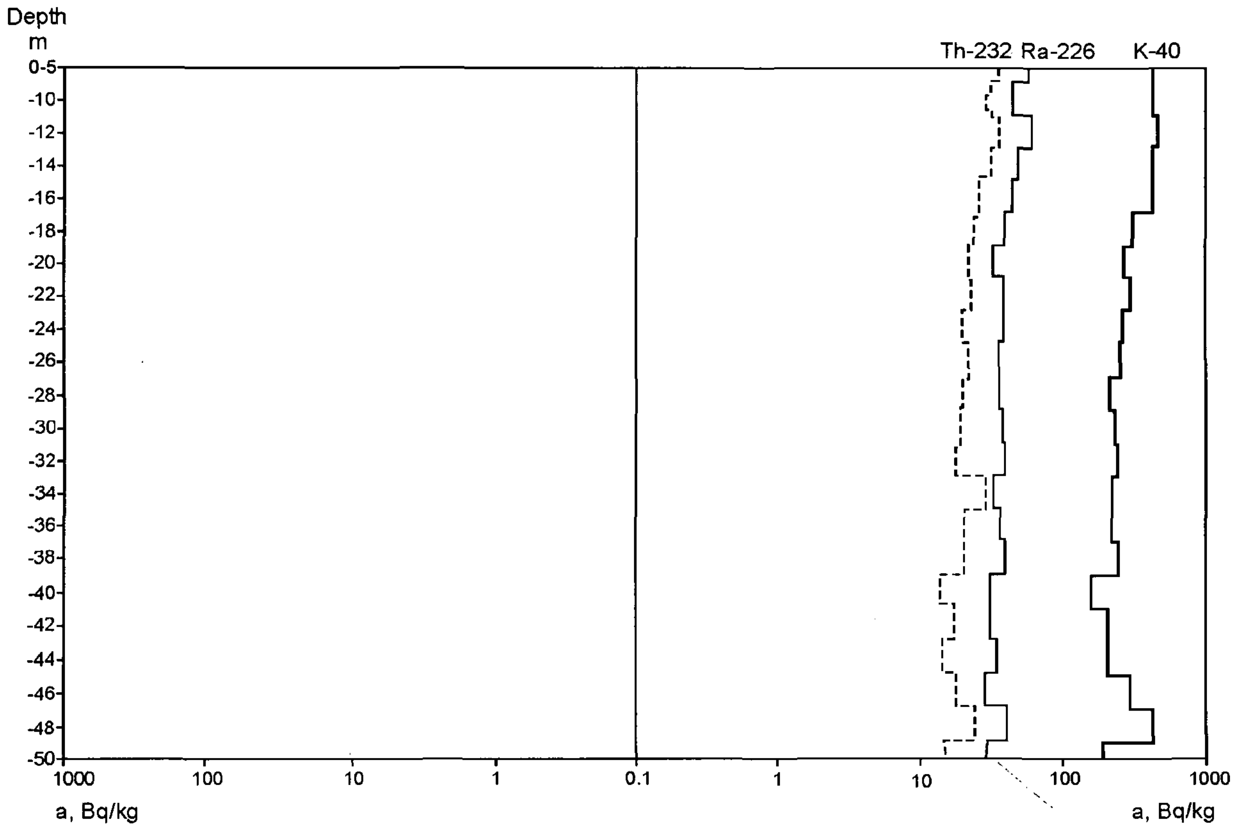


Fig. 11. The variation of natural and artificial isotopes vs depth in borehole Tó–29

11. ábra. A Tó–29 fúrás mintáinak radioaktivitása

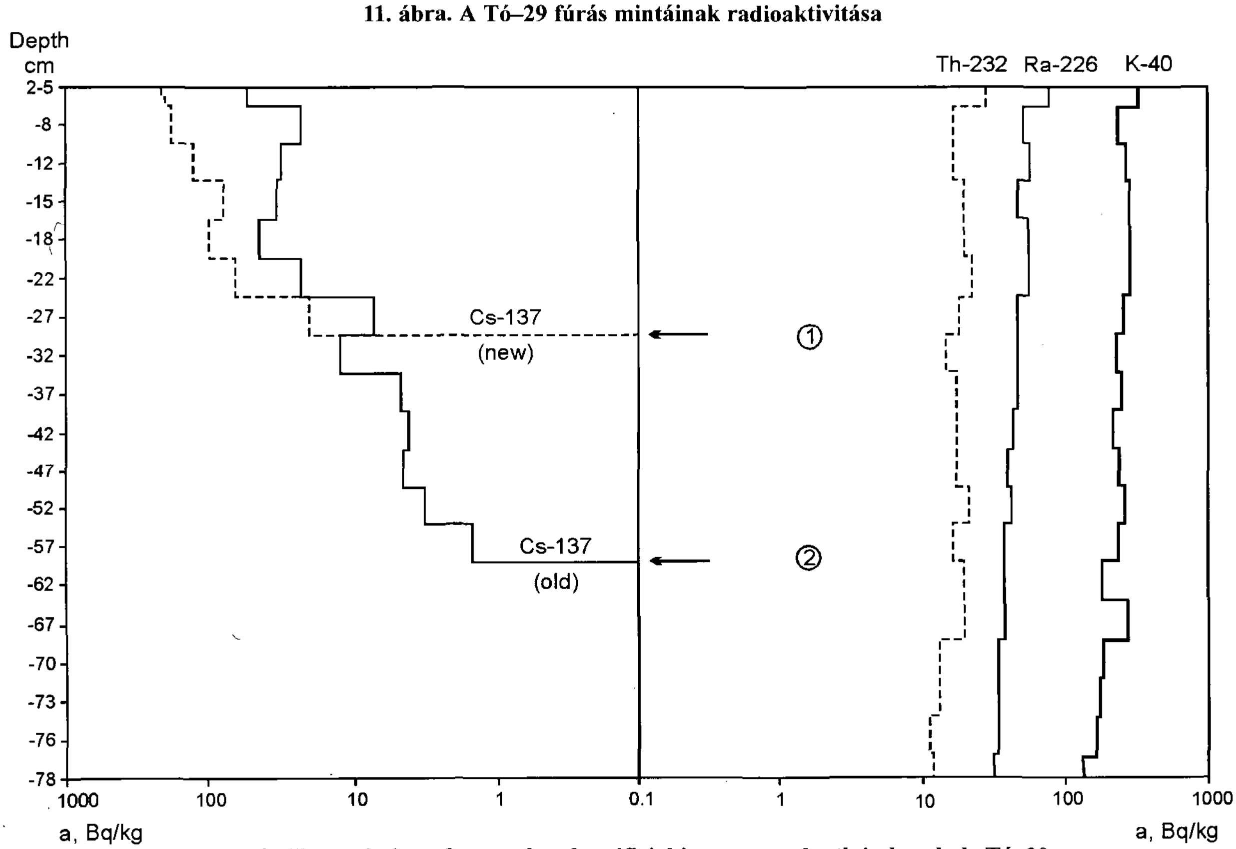


Fig. 12. The variation of natural and artificial isotopes vs depth in borehole Tó–30
1, 2. For legend see Fig. 10

12. ábra. A Tó–30 fúrás mintáinak radioaktivitása
1–2. Mint a 10. ábránál

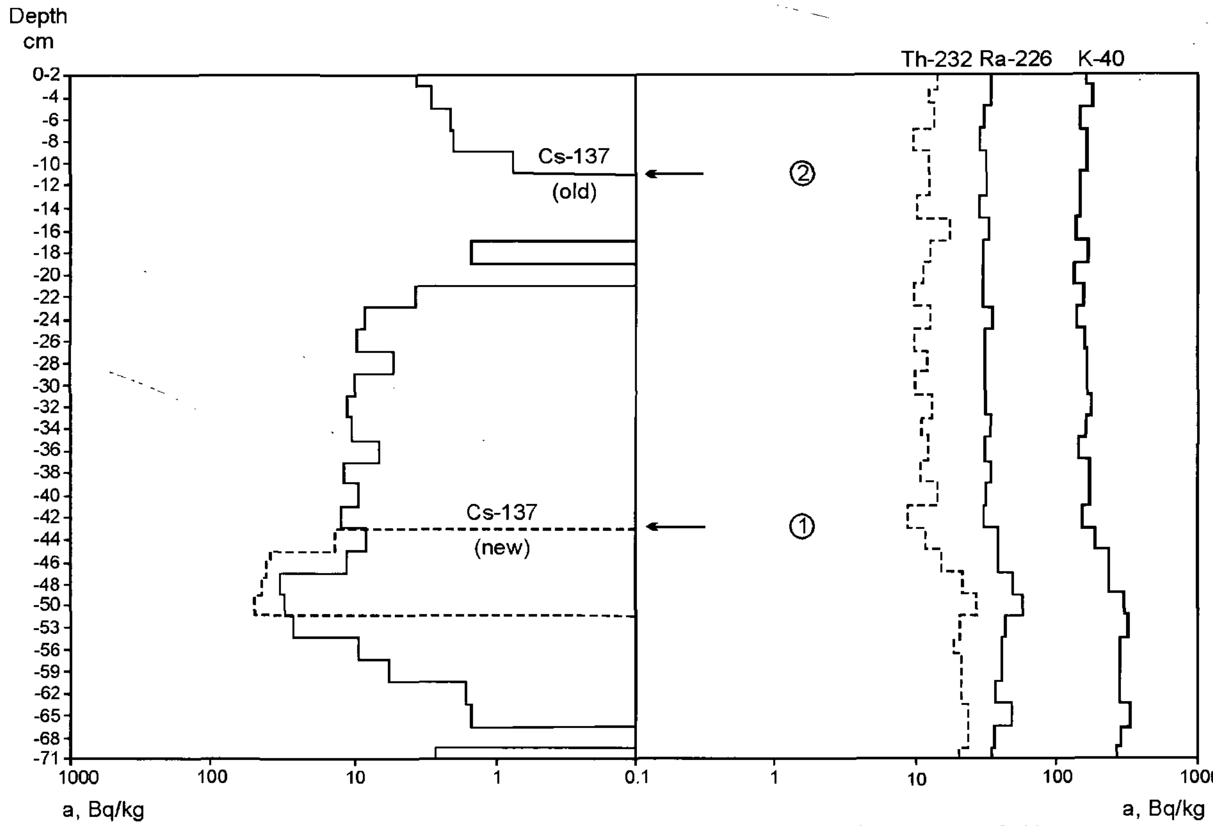


Fig. 13. The variation of natural and artificial isotopes vs depth in borehole Tó–33
1, 2. For legend see Fig. 10

13. ábra. A Tó–33 fúrás mintáinak radioaktivitása
1–2. Mint a 10. ábránál

pended solids in the water was large (the area of borehole Tó–33), where it was of average value (boreholes Tó–22 and Tó–30), and where mud transport was likely (borehole Tó–29).

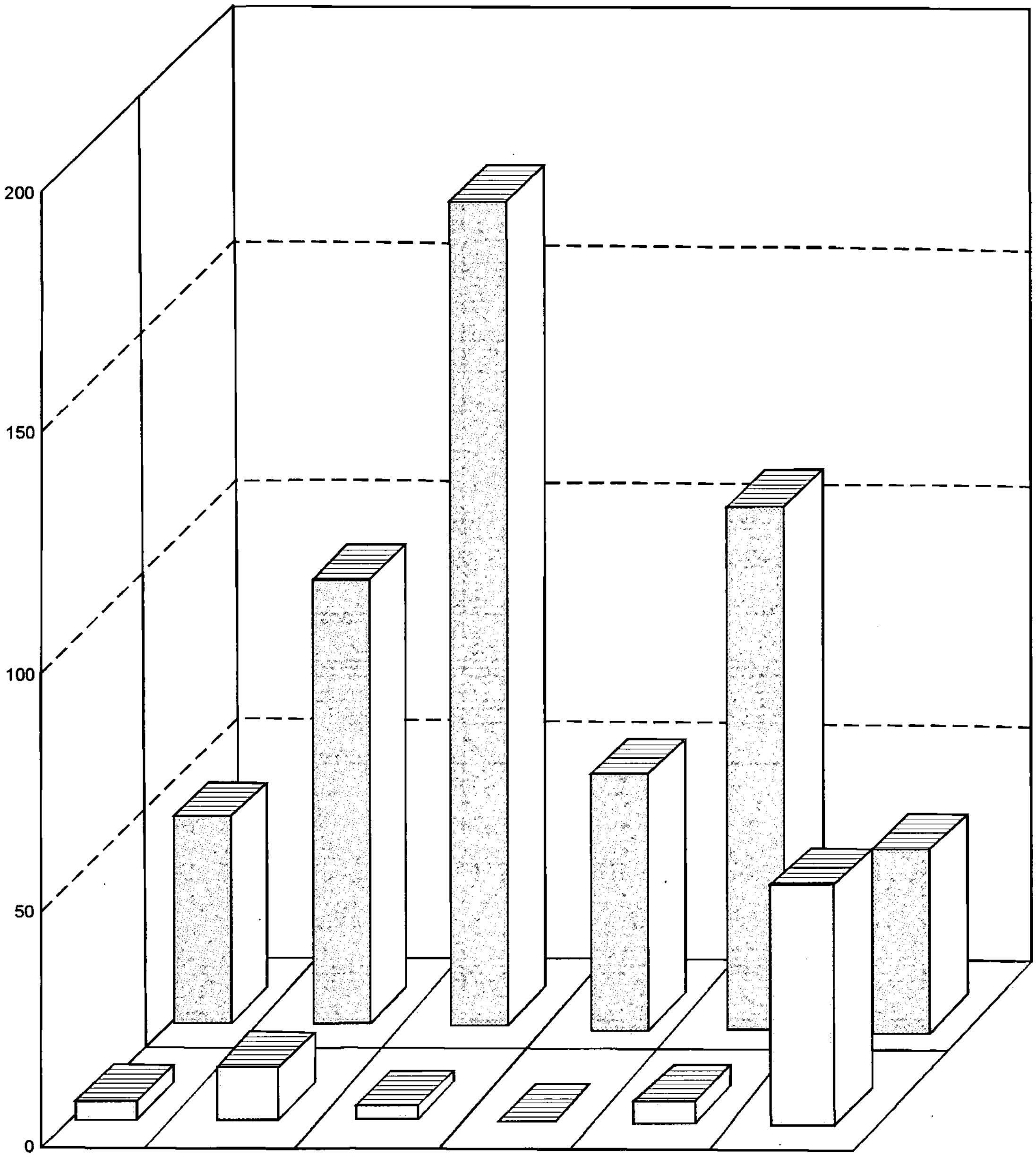
For the activity values for these four sections, see Figs. 10 through 13. It is clearly visible that the activity value shows a similar trend in all the four cases, that is, gradually decreases, for borehole samples Tó–22, Tó–29 and Tó–30, with an increasing depth. This phenomenon may be linked with the greater organic matter content of the surface layers of the mud and with its higher capacity to absorb uranium and thorium. It can also be observed that the amounts of the three major isotopes of natural origin (^{238}U, ^{232}Th, ^{40}K) are well correlated. This agrees with the conclusions deducible from the other sedimentological, soil physical, mineralo-petrological and geochemical parameters of the beds. All these show that the samples from these three boreholes were undisturbed.

For borehole Tó–33, the situation is different. The decreasing trend observed in the other sections is observed to a depth of 41 cm only beyond which in the 46 to 51 cm interval the activity shows some increase. The ratio of the isotopes is nearly constant even in the anomaly interval. In deeper layers the activity concentration of all the three natural nuclides remains constant. It should be noted that these stable values are similar to the values of subsurface ^{238}U, ^{232}Th and ^{40}K activities of samples from the other boreholes.

Caesium which is generated by anthropogenic contamination shows a completely different picture. The shapes of the curves are similar in the boreholes Tó–22 and Tó–30 but the two peaks of activity are at different depths. In the section of Tó–22 ^{137}Cs ("new") and ^{137}Cs ("old") appear at a depth of 11 cm and 21 cm, respectively. In borehole Tó–30 ^{137}Cs ("new") and ^{137}Cs ("old") appear at a depth of 31 cm and 55 cm, respectively. In the section of Tó–29 no ^{137}Cs isotope could be detected either from the Chernobyl accident or from nuclear tests. In the section of Tó–33, the old caesium can be detected almost continuously, nearly in every layer while new caesium only appears at a depth of 45 to 51 cm. Comparing this very surprising result with the distribution of natural isotopes by depth allows us to conclude that the profile is likely to show traces of large scale sediment reworking.

Our results prove that in the mud of Lake Balaton it is possible to detect the artificial radioactive isotope contamination which entered the atmosphere from the 50's. In some cases it was possible to identify two peaks of radioisotopes. The first peak (old ^{137}Cs) is associated with atmospheric nuclear tests which were carried out before the Nuclear Test Ban of 1962. The second peak (new ^{137}Cs) is caused by the radio-isotopes which entered the atmosphere during the Chernobyl reactor accident.

These results allow the determination of the rate of mud deposition in the area around boreholes Tó–22 and Tó–30. Assuming undisturbed hydrological conditions,

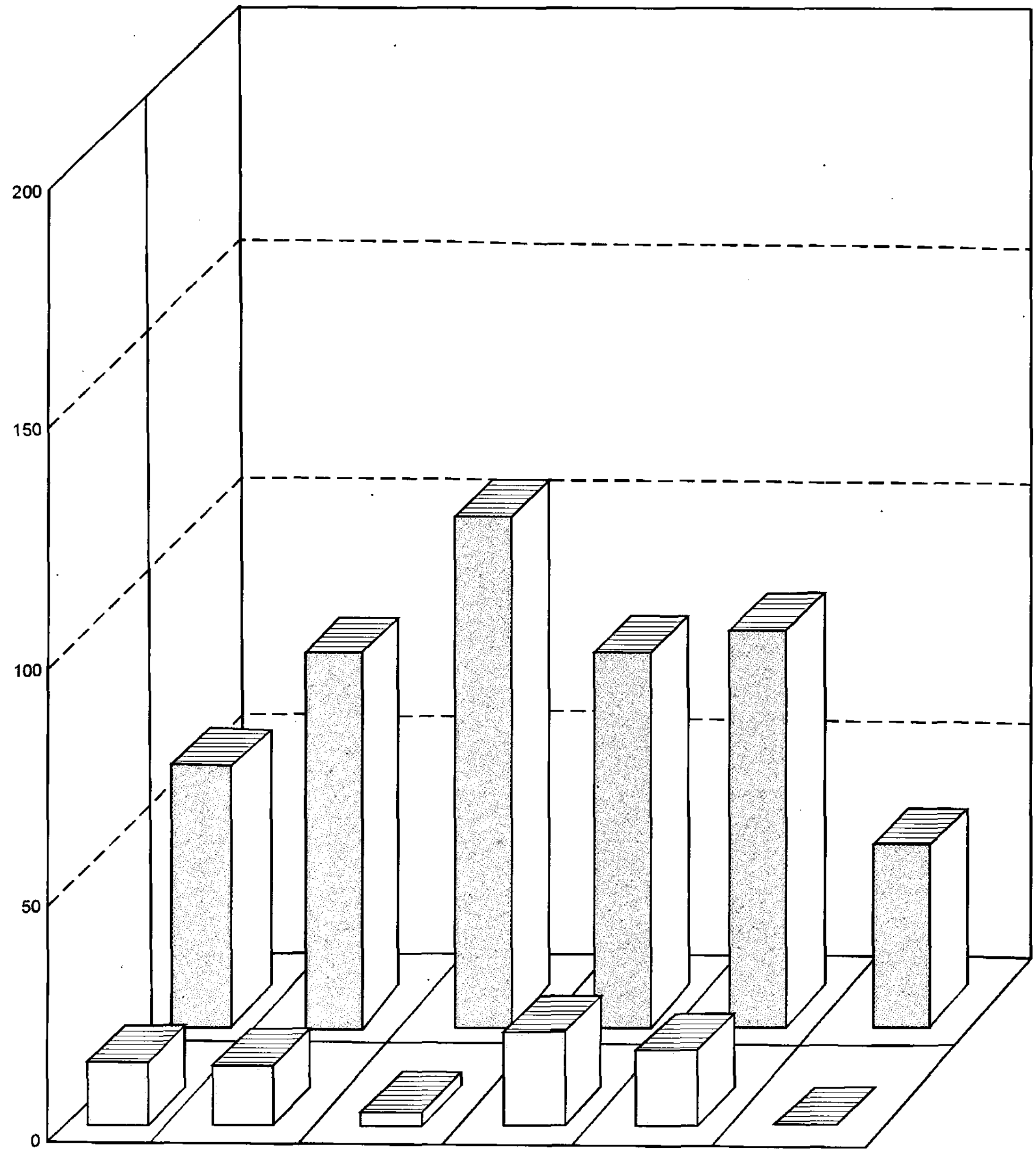


sampling / mintázás						dredging kotrás
1	2	3	4	5	6	
43.1	93.3	173	53.05	110	36.8	before / előtt
3.36	10.4	2.9	0	4.62	49.83	subsequently / után

Fig. 14. ^{137}Cs isotope values prior to and subsequently to experimental dredging in the Keszthely Bay (Bq/kg dry material)

14. ábra. A kotrás előtti és utáni radioaktivitás összehasonlítása (^{137}Cs izotóp, Bq/kg szárazanyag)

this rate for the past forty years was 1.4 cm/year in the middle of the Szigliget Bay (Fig. 1: around Tó–20), and 0.5 cm/year at the eastern boundary of the bay. The rate of sedimentation shows changes both in space and time as shown by the position of the contamination resulting from the Chernobyl accident. The rate of mud deposition is increasing. The rate in the past 5 years 6 cm/year in the centre of the bay and 2 cm/year at the margin. Data from the borehole Tó–29 indicate underwater sediment transport. Borehole Tó–33 is also indicates further sediment accumulation in the lake. The occurrence of both ^{137}Cs isotopes peaks in the depth range of 2 to 3 m indicates that the storms over Lake Balaton disturbed the mud to a depth of approx. 2 to 3 cm.



sampling / mintázás						dredging kotrás
1	2	3	4	5	6	
54.3	79	108	79	88	38.5	before / előtt
13	12	3.3	19.9	17	0	subsequently / után

Fig. 15. ^{210}Pb isotope values prior to and subsequently to experimental dredging in the Keszthely Bay (Bq/kg dry material)

15. ábra. A kotrás előtti és utáni radioaktivitás összehasonlítása (^{210}Pb izotóp, Bq/kg szárazanyag)

Case study of using ^{137}Cs isotope measurements applied to solve a specific environmental problem in Lake Balaton

A description of the task and the conditions

In the last decade the rate of eutrophication and sedimentation have shown an extraordinary increase in Lake Balaton, particularly, in the Keszthely Bay (Fig. 1: around Tó–31). The Water Control Authority has taken efficient and powerful measures to save the lake including the establishment of sediment retaining reservoirs at Kis-Balaton, and dredging of the bay.

A hydromechanical dredger equipped with a special head was manufactured within the PHARE program. A set of geological, geophysical and geochemical tests were carried out to evaluate the dredging efficiency of the dredger deployed in the Keszthely Bay.

Solution, results

In-situ geophysical measurements and sampling at 6 designated sites in the dredging area were commissioned by the Siófok Office of KDT-VIZIG, in order to have a better knowledge of the physical, mineralogical and geochemical properties of the sediments.

Both the sampling and the in-situ geophysical measurements were made twice, prior to and subsequently to dredging.

Well logging was performed using a ^{137}Cs tool at the time of coring, by the Well-Logging Team of MÁELGI. The density log was interpreted by G. SZONGOTH using the techniques developed for deep boreholes to determine the specific density of formations. The precise knowledge of mud density by depth was important in order to determine the amount of the dredged material and the dredging efficiency. As shown by the measurements the boundary between mud and water is not sharp. The density is gradually increasing from 1.0 g/cu.cm to 1.5 g/cu.cm, then it levels out at this value at about 1 m depth.

Measuring the density after dredging, we found that the limit of 1.5 g/cu.cm was reached at a less deep level. This has led us to the conclusion that a layer with a thickness of approx. 20 cm was removed by the dredging. The results from the in-situ measurements were also suitable for use in the follow-up of the result of an earlier geophysical survey. The contour map compiled from the data of seismo-acoustic surveys in 1987 shows the thickness of this upper mud layer with a volumetric weight not exceeding 1.5 cu.cm.

At geophysical measurement stations samples were also taken for isotope geochemical tests. The aim of these tests were (1) to control the success of dredging, (2) to make clear whether there is any natural motion of mud at the boundary between the water and sediment, and (3) to assess the rate of mud accumulation in the particular region. Samples were tested by high sensitivity gamma-spectrometry. We used the top and bottom 5 cm slabs of the 30 cm long cores. The Department for Radiology of the Institute for Food Control measured the activity of old and new ^{137}Cs isotopes and gamma-radiating isotopes in the samples. The variation of activity of ^{137}Cs and some radioactive isotopes of natural origin (^{210}Pb, ^{40}K) can be explained by the distribution of phytoplankton in various parts of Lake Balaton. The chemical elements which are concentrated by organisms appear in the sediment after their death.

The isotope geochemical analyses of samples taken after dredging show that the dredging was successful (Figs. 14 and 15), although the activity concentration values measured in the upper samples (particularly, ^{137}Cs and ^{210}Pb) indicate that some mud is transported back to the dredged area. In the area of dredging in the north-western part of the Keszthely Bay about 1.5 to 2 km offshore of Keszthely pier the rate of deposition was approx. 1 cm/year.

Acknowledgements

The projects "Radio-carbon dating on peat samples from Lake Balaton", and "Measurement of stable isotope ratio values in deposits of Lake Balaton or on older deposits" were financed by the Central Office of Geology. The fund for "The $\delta^{18}O$ analysis of the water of Lake Balaton" and "The Measurement of natural and artificial isotope ratios of deposits in Lake Balaton" were granted by OTKA (National Scientific Research Fund) 550. The Siófok Office of KDT-VIZIG entrusted us to perform the environmental assessment in the Keszthely Bay. The authors express their thanks to these institutions for their support of the work described in this paper.

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IZOTÓP-GEOKÉMIAI VIZSGÁLATOK ÉS EREDMÉNYEIK A BALATON FÖLDTANI KUTATÁSA SORÁN

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Tárgyszavak: izotóp-geokémia, oxigénizotóp vizsgálatok, Balaton, negyedidőszak, radiokarbon kor

ETO: 550.4(439:285Balaton) 504.064(439:285Balaton) 550.84(439:285Balaton)

A Balaton komplex földtani kutatása során, kitűzött feladataink érdekében több új módszer bevezetésére is sor került. Ezek közül igen hatékonynak bizonyultak az izotóp-geokémiai vizsgálatok. Segítségükkel sikerült néhány, a Balaton környezeti állapotával összefüggő kérdésre választ kapnunk (a feliszapolódás sebessége, az iszap fizikai tulajdonságai, víz alatti mozgása stb.), illetve korábbi ismereteinket gyarapítani és pontosítani (a Balaton keletkezési kora, környezetének klíma-rekonstrukciója stb.). Az elért eredményeink közül a legfontosabbak a következők:

(1) A Balaton területén a tőzegesedés a Posztglaciális elején indult meg (Bölling), de ez a folyamat a tó egyes részmedencéinek területén időben kb. 1500 évig elhúzódott, és az Allerödben volt a legelterjedtebb.

(2) A Balaton autochton karbonát üledékein és a Gastropodák karbonát vázán mért oxigénizotóp-arányokat elsősorban a víz párolgása befolyásolja. Utóbbi közvetve függ a térség éghajlati viszonyaitól is. A mért oxigénizotóp-arányokból jól nyomon követhető az éghajlat fokozatos felmelegedése a holocén kezdete óta.

(3) A balatoni üledékek karbonát-tartalmának túlnyomó része helyben képződött és csak jelentéktelen része szállítódott be a vízgyűjtőről.

(4) A Balaton-víz $\delta^{18}O$ értékének és az időjárási viszonyok alakulásának összehasonlító vizsgálatából megállapítható, hogy a Balaton vizének intenzív párolgása miatt annak oxigénizotóp aránya közelít a tengervízéhez és jelentős mértékben különbözik a magyarországi folyók vize és a csapadékvíz megfelelő értékétől. Magyarországon a csapadékvíz átlagos $\delta^{18}O$ értéke –9,5%, a tengervízre vonatkoztatva. A Balaton vizének oxigénizotóp arányában jól látható évszakos változások figyelhetők meg.

(5) A balatoni iszapban meglévő szervesanyag egy része korábban felhalmozódott biológiai szén újrafelhasználásából származik. Ez a folyamat a tó kialakulása óta tart, s a ^{13}C relatív feldúsulásával jár.

(6) A Balaton iszapjában jól nyomon követhetők az 1950-es évektől napjainkig légkörbe kerülő mesterséges radioizotóp-szennyeződések. Megjelenésükkel és maximum csúcsaikkal meghatározhatóvá vált az iszap-felhalmozódás sebessége. Nyugodt hidrológiai körülmények mellett ez az érték 0,5 cm/év és 1,4 cm/év között mozog, a mérési pontok helyének függvényében. A feliszapolódás mértéke időben is változik és az utóbbi években rohamosan nő. A Balaton néhány pontján vízalatti üledék-elhordás, máshol üledékfelhalmozódás megy végbe. Méréseink tanúsága szerint a balatoni viharok hatására max. 2–3 cm vastagságú réteg kavarodik fel.

ANN. REP. OF THE GEOLOGICAL INSTITUTE OF HUNGARY, 1992–1993/II: 85–92 (1999)

ARSENIC-BEARING ARTESIAN WATERS OF HUNGARY

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Manuscript received in 1994.

Keywords: artesian water, drinking water, arsenic content, geochemistry, Great Hungarian Plain

UDC: 550.4(439.14) 556.33(439.14) 549.24:556.33(439.14)

The anomalous arsenic content of some communal drinking waters produced from artesian aquifers of the Great Hungarian Plain was recognized in 1981/82 by public health authorities in Hungary. Arsenic in excess of the sanitary threshold contcentration could be detected in the artesian waters of extensive areas providing the water supply of nearly half a million of consumers. These increased levels caused by geological and geochemical processes. Short term solutions for the most urgent problems were found by investing many thousand of millions of Hungarian forints, but finding long term solutions remained a task for the future.

The hydrogeochemical study started in 1993 was aimed at the establishment of the knowledge still missing up to that time but being indispensable for the further advance. This paper gives the summary of the first results obtained during 1993.

1. By carrying out a new evaluation of the data base built up by data on 6500 wells and using GIS we plotted a map of arsenic bearing waters. These areas turned out to be considerably bigger than it has been known hitherto.

2. On the ground of the two-peaked lognormal frequency distribution of the concentration values of arsenic we identified its large-scale enrichment as the result of well definiable and characteristic geochemical processes.

3. It was found that the arsenic-bearing waters were formed in the geological–geochemical environment of the Quaternary. The process went on during several phases of the early diagenesis transforming the fluvial, floodplain and paludal sediments. According to the evidence the enrichment of arsenic is related to adsorption processes taking place on the surface of colloid oxi-hydroxides of Fe, while its remobilization was the result of reducting bacterial processes following the burial of the sediment.

4. On the basis of the new results the areas of the possible occurrence of arsenic-bearing waters could be contoured, thus pointing to new targets for further study.

Preliminaries

The poisonous effect of arsenic and its soluble compounds is well known since the ancient times. Later on it has been recognized by medical investigations that by receiving small doses of arsenic over a long period, the living organism gradually accumulates it; this enrichment may lead to inadmissible consequences, such as increased probability of the development of malignant tumours, diseases of the vascular system and —first of all— of serious damages to the skin. In accordance with the recommendations of the World Health Organization the Hungarian standard (MSz 450/1–78) puts the upper limit of the acceptable arsenic content in drinking waters to the value of 0.05 mg/l, i.e. to 50 μg/l.

Since the 1981/82 survey carried out by the Hungarian public health authorities we know that in certain areas of the country the arsenic content of subsurface waters is considerably higher than the limit acceptable for the public health. Some half a million consumers had been affected by this chemical feature of the drinking water and as a consequence of this situation the construction of a new water supply system having 150 thousand cubic metre/day capacity was needed.

During the decade which elapsed since then the difficulties caused by the arsenic bearing waters for the communal water supply have been considerably reduced. The governmental programme of improving the water quality, which was established in 1983 and is in force even to-day resulted in the reduction of the arsenic content below the permissible threshold concentration in the case of most of the communal water works concerned. The investment costs ran to several thousands of millions of Hungarian forints. Certain areas however, like the Sárrét and Nagykunság regions and the towns of Gyula and Orosháza are difficult to supply with healthy drinking water throughout the year. The problem presents itself mainly during the summer season. (Verbal information given by Z. KÁRPÁTI.)

In its most recent recommendations of the World Health Organization (1993) urges the considerable lowering of the limit for the arsenic content in drinking water, to a level as low as 10 μg/l eventually. This means that we should not overestimate the results achieved in Hungary so far, but consider them as the most urgent first steps taken. The proposed lowering of the limit puts into question not only the efficiency of the measures taken for the reduction of arsenic content (modification of the operative processes in water works, dilution, extraction of As, development of new water reserves etc.) in their present form, but the results achieved in the improvement of the water quality on the whole as well. What was done so far can be considered as partial measures at best and further action is called for.

It is certain however that the solution in the long run may be reached by the complete re-investigation of the entire scope of the problem. In the search for new solutions the hydrogeological and hydrogeochemical investigations have also a role. Realising this gave the impetus for launching the geochemical investigation of arsenic bearing waters by a survey of the entire national territory.

Results of the research work done prior to 1993

The recognition of the abnormally high arsenic content in the artesian and ground waters of Hungary is the achievement of the professional staff of the public health service, and being also the result of a process lasting some fifty years.

Medical and sanitary investigations concerning the occurrence of arsenic

The first signs of the anomalous arsenic content in some domestic drinking waters appeared as cases of chronic poisoning in the lowland areas between the Danube and Tisza rivers during the forties and fifties. It was supposed at first that these cases might be attributed to the pollution of the groundwaters from the surface — thus being caused by human negligence— and were regarded as local problems only. (HORVÁTH et al. 1980.)

The essential change in appreciating the problem and its sanitary importance was brought about by the results of the national survey concerning the arsenic content of the communal drinking waters. The surveys carried out in 1981/1982 under the direction of the National Institute of Public Health (Országos Közegészségügyi Intézet — OKI) have found (CSANÁDY et al. 1985) that:

— In the drinking waters of 148 settlements scattered over the area of six counties (Bács-Kiskun, Békés, Csongrád, Hajdú-Bihar, Heves and Szolnok) the amount of the arsenic exceeded the 50 μg/l sanitary limit. Almost half of the settlements concerned was found in Békés County.

— Within the "arsenic-bearing areas" the arsenic content of the communal drinking waters in 50% of the cases exceeded twice the amount of the sanitary limit (by being over 100 μg/l). The peak value observed reached 560 μg/l.

— The size of the population affected (400,000) by the problem was higher than in anay similar cases known elsewhere in the world documented up to that time (Taiwan, USA, Canada, Argentine, Chile).

— The extraordinary high arsenic content of the artesian aquifers tapped for communal water supply is a phenomenon which in spite of earlier opinions of the medical circles was not caused by external pollution, but being the result of natural —i.e. geological— processes.

Geological–geochemical investigation of the arsenic-bearing artesian waters

The efforts of a decade aimed at the survey of the arsenic content of artesian drinking waters and concentrated on the urgent reduction of it resulted in a significant improvement of the water supply, but at the same time the full-scale investigation of the problem including first of all its geological–geochemical aspects was left aside. Thus:

— The anomalies of the occurrence of arsenic were not identified in geological sense: i. e. by taking into consideration the genetical conditions of the phenomenon. The potentially endangered aquifers and their extent were not yet determined either.

— The effect of the exploitation of aquifers on the arsenic content of the water produced was not investigated.

— The role of the trace elements associated with arsenic in influencing the toxicity was not taken into consideration.

The initiative to carry out these investigations was taken by two research institutes simultaneously.

The Hydrogeological Department of the Geological Institute of Hungary (MÁFI) began the hydrogeological mapping of Hungary in 1983 under the leading GY. TÓTH. Within the scope of the general reconnaissance concerning the distribution of trace elements the amount of arsenic had been determined in almost one thousand samples of drinking water, but the evaluation of the results was not completed.

The pilot project for the geological and geochemical study of arsenic-bearing waters was steered by the "ad hoc" academic committee organized in Szeged for the execution of assignments given by the Council of Békés County and later on also by the MÁFI. This committee was acting under the leadership of T. SZEDERKÉNYI, with MRS. VARSÁNYI, B. MOLNÁR and M. ERDÉLYI collaborating in the research work. The results obtained were published in 1990 (SZEDERKÉNYI et al. 1990). At the outset the survey had covered the area of Békés County only, but later it was extended to cover the entire southern part of the Great Plain. These geochemical, genetical (VARSÁNYI 1990, SZEDERKÉNYI 1990), facies (MOLNÁR 1990) and hydrogeological (ERDÉLYI 1990, 1991) surveys were of fundamental importance for all further research activity.

Results of the hydrogeochemical investigation of the arsenic-bearing artesian waters carried out in 1993

The countrywide geological–geochemical survey of the arsenic-bearing waters was started by the Geological Institute of Hungary at the end of 1992. This activity formed part of a hydrogeochemical project. In 1993 the results of the investigations carried out by the public health authorities and of those of geological–geochemical character done up to that time were re-evaluated according to geochemical concepts. In collaboration with the National Institute of Public Health (OKI) a national data base of the arsenic-bearing waters was set up and processed in part by GIS in that year. The data base and GIS have made it possible to determine the spatial extension of the arsenic-bearing artesian waters, their geological and geochemical environment, and the geochemical processes responsible for their formation.

Our growing data base now includes 9600 analysis results of the arsenic content found in 6499 water wells of 1466 settlements of the country. Hydrogeological and hydrochemical and well completion information is also included. Seventy percent of the analytical results on arsenic obtained by the highly sensitive hybrid-forming AAS procedure were given to us by public health services; of this, nearly 20% was received from the OKI. The contribution of the MÁFI is about 10%, while the remaining 20% of the data were obtained from water works.

New concepts on the geological–geochemical environment and genetical conditions of the arsenic-bearing artesian waters

Due to the very uneven areal distribution of the samples, we took into consideration for each of the settlements the data of only one water well, the one that contained the greatest amount of arsenic.

We plotted the frequency of values on plots with logarithmic scaled axes. The smoothed curve of arsenic distribution in the chosen water wells is characteristically bimodal (Fig. 1).

The distribution pattern indicates that:

— The arsenic content of the analysed artesian waters lies in the 1–10 μg/l interval — thus being in accordance with published data in scientific publications.

— The appearance of the second peak of the concentration-frequency can be interpreted as a peculiar process of the enrichment of arsenic which causes an anomaly both in geochemical and sanitary sense. The geochemical anomaly limit is likely to be in the 12–25 μg/litre concentration interval.

— According to the new data base the arsenic content of the drinking water exceeds the sanitary limit in 358 settlements. By taking into consideration the greatest values of the arsenic content found at separate settlements, our ideas on the gegraphical extent of the arsenic-bearing artesian waters have to be modified (Fig. 2).

— Besides the areas mentioned hitherto with emphasis (Békés and Csongrád Counties moreover the southern part of the Danube–Tisza Interfluve) arsenic-bearing waters occur also in the whole area of the Danube–Tisza Interfluve, in the Nagykunság, Jászság and southern Heves areas, in Szabolcs–Szatmár County, in the Bihar and Hajdúság regions and in extensive marginal zones of the Nyírség.

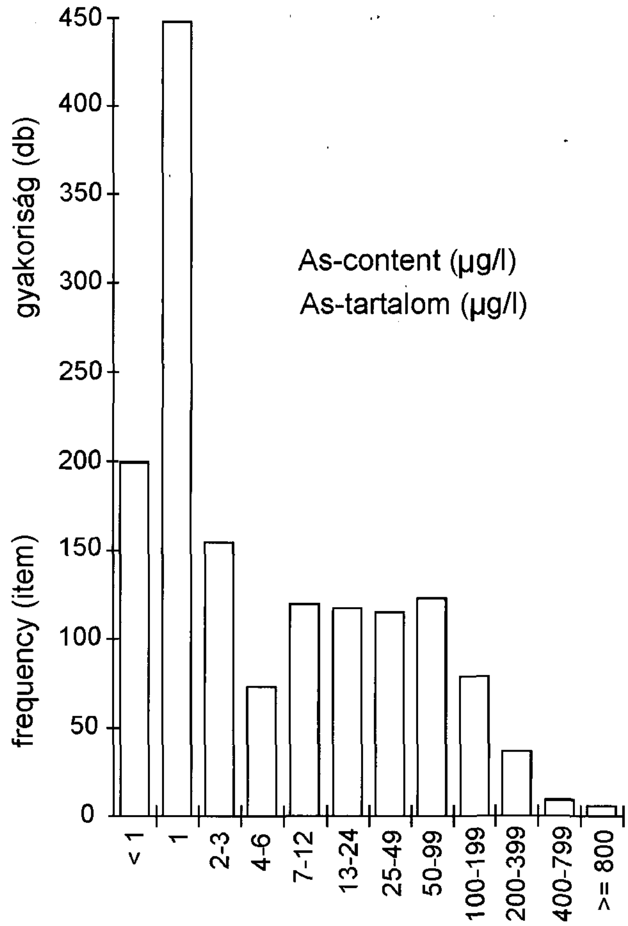

Fig. 1. Frequency of the maximum As-contents tested in the artesian waters of the settlements

1. ábra. A települések rétegvizeiben mért legnagyobb As-értékek gyakorisága

— Scattered geochemical anomalies of arsenic can be found between the Sajó and Hernád rivers, along the Dráva river, on the flood plain of the Kapos and Zala rivers and, according to recent information, in the Szigetköz area as well.

— Due to lack of adequate information the danger to public health can not be established in the southern parts of Pest, Heves and Borsod Counties.

Current data suggest that these areas, along with in the deeper levels of the water base of the Kisalföld region, belong to the unfavourable zone.

Fig. 3 shows the distribution of the arsenic-bearing aquifers by depth in Békés County almost all of which is a contiguous anomaly. Arsenic-bearing aquifers are most frequent there in the 300–400 m depth interval.

— Extraordinary enrichments of arsenic can be found in thermal waters ascending from considerable depths as

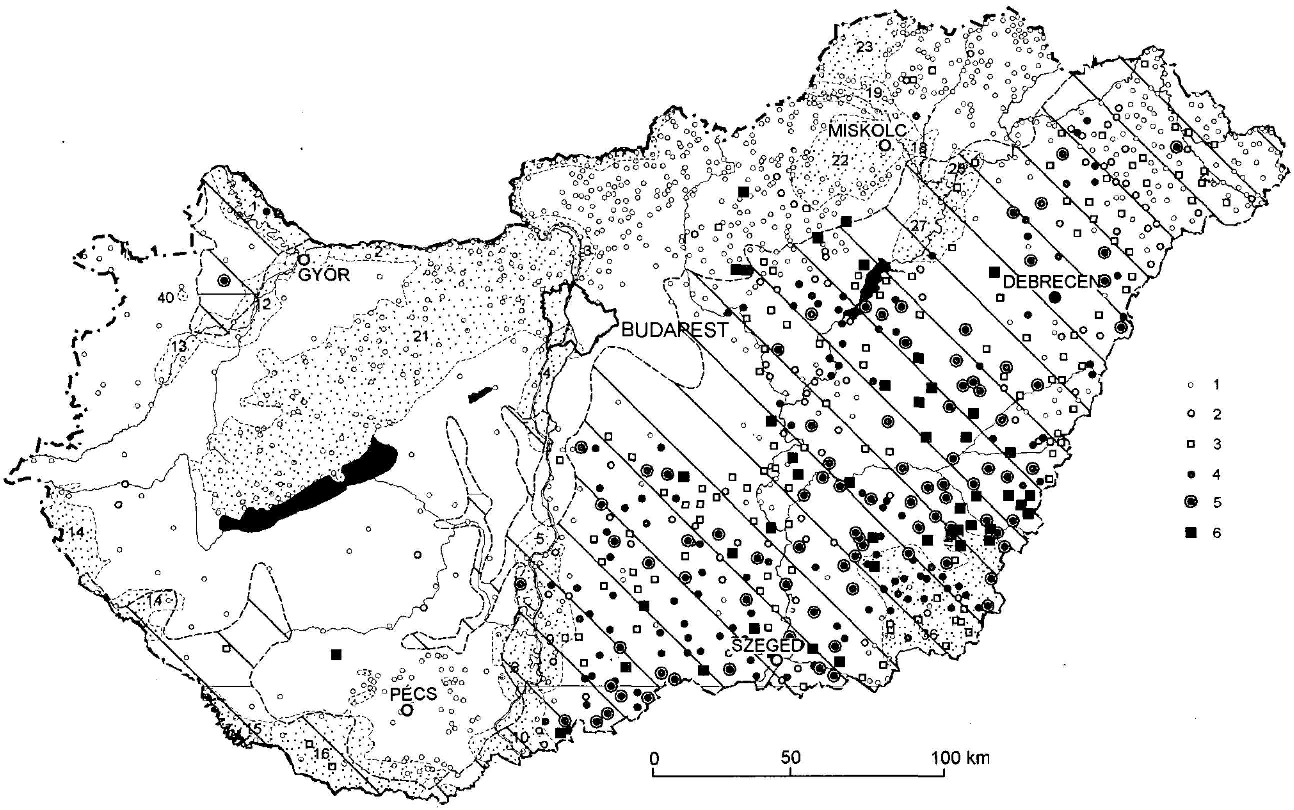

Fig. 2. The maximum As-contents tested in the settlements investigated; (the sanitary threshold contentration is 50 μg/l in Hungary)
1. <12.5, 2. 12.5–25, 3. 25–50, 4. 50–100, 5. 100–200, 6. >200 μg/l, 7. Territories of Quaternary sedimentary rocks and sediments with thickness more than 50 m, 8. Protected water-bearing areas (after F. FRANYÓ)

2. ábra. A vizsgált településeken mért legnagyobb arzéntartalom; μg/l (az egészségügyi határérték 50 μg/l)
1. <12.5, 2. 12.5–25, 3. 25–50, 4. 50–100, 5. 100–200, 6. >200 μg/l, 7. Az 50 m-nél vastagabb negyedidőszaki üledékek elterjedése (FRANYÓ F. után), 8. A védett vízbázisok területe

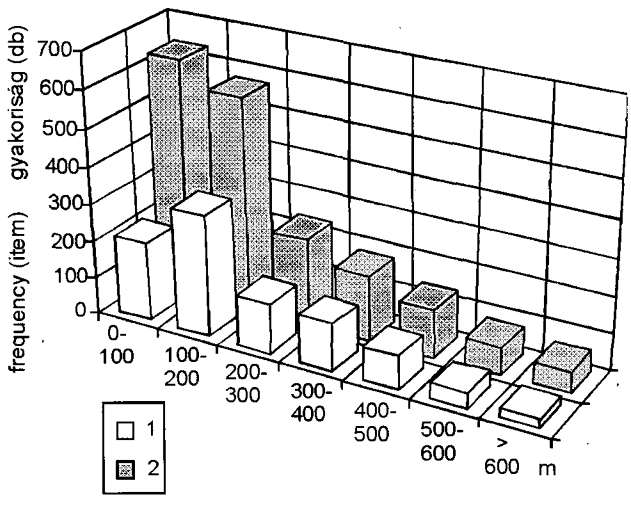

Fig. 3. The As-anomalies vs depth in Békés County
1. Anomalous samples, 2. The total of the samples

3. ábra. A Békés megyei arzénanomáliák a mélység függvényében
1. Anomális (As>50 μg/l) minták 2. Összes minta

well. It is proven however that neither areal nor, consequently, genetical connection exists between the arsenic-bearing waters of the shallow and deep aquifers.

Fig. 4 shows the percentage of shallow depth As anomalies as a function of their depth in Békés County. Fig. 4 indicates two important facts:

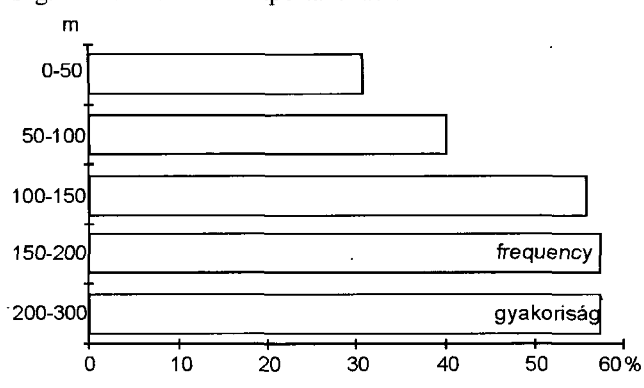

Fig. 4. Percentage of the anomalous samples to the total vs depth inside the 0–300 m interval in Békés County

4. ábra. A Békés megyei sekély mélységű arzénanomáliák az összes mintához viszonyított %-os arányának változása a mélység függvényében

— The frequency of the shallow-depth As anomalies decreases towards the present surface, thus it can be assumed that their origin is not connected to recent or very young supergene processes.

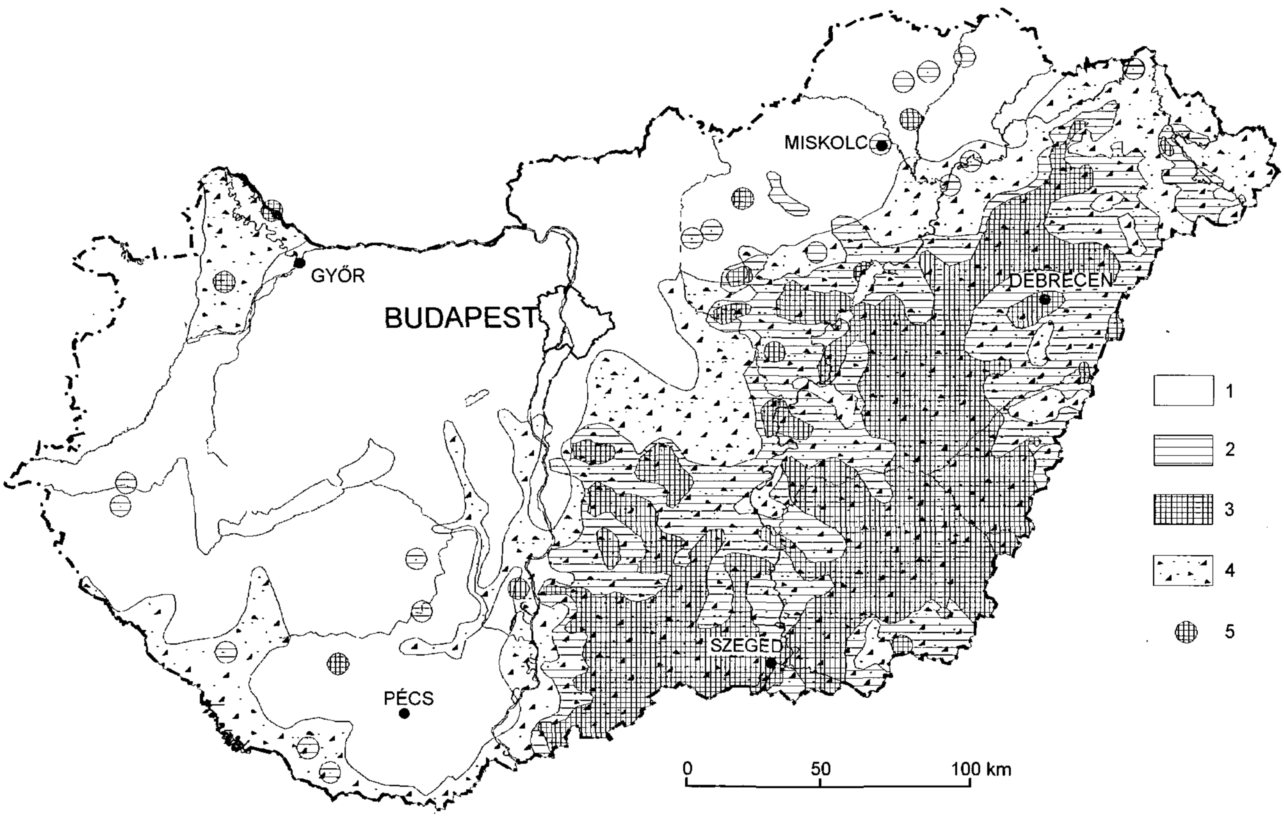

Fig. 5. Areas of the known (1–3) and possible (4) occurrences of As-bearing artesian waters based the maximum As-contents tested in the settlements

1–3. The As-content of the artesian waters (μg/l): 1. <12.5, 2. 12.5–50.0, 3. >50.0, 4. Areas of the possible occurences of the As-bearing artesian waters, 5. Single tests

5. ábra. Az arzénes rétegvizek ismert (1–3) és lehetséges (4) elterjedése a településeken mért legnagyobb arzéntartalom a l a p j á n

1–3. A rétegvizek arzéntartalma (μg/l): 1. <12.5, 2. 12.5–50.0, 3. >50.0, 4. Az arzénes vizek lehetséges megjelenési területei, 5. Egyedi arzénadatok

— In the phreatic zone (taken in the broad sense) the frequency of the anomalies reaches 30%. This zone is only inadequately investigated all over the country.

The stratigraphical and facies conditions determining the occurrence of the arsenic-bearing artesian waters are shown by Fig. 5. Contours are drawn according the manuscript map of F. FRANYÓ (1993). These show an overlap with the more than 50 m thick Quaternary sediments. Consequently this map verifies former views regarding to the geological background of the extent of As anomalies (CSÁKI et al. 1983).

The stratigraphic dating and facies analysis of the aquifers storing arsenic-contaminated waters is mostly still outstanding. Available data suggests that these waters are connected mainly to sediments of fluvial, flood plain and paludal origin. These formations are described in the monograph of A. RÓNAI (1985). It is remarkable that there is no enrichment of arsenic in the loess areas of the same Quaternary age.

Geochemical relationships of the origin of arsenic-bearing artesian waters

The geochemistry of the arsenic, the conditions of its enrichment and mobilization moreover the effects of oxidation–reduction and adsorption processes of the sedimentation on the distribution of the arsenic are well known in general (BELZILE et al. 1990, FERGUSON et al. 1972, HEM 1977, KANAMORI 1962, MATISOFF et al. 1982, ONISHI et al. 1955, SZÁDECZKY-KARDOSS 1955). As usually the practical difficulties arise from the fact that theoretical knowledge can be applied to complex and variable natural systems with certain restrictions and simplifications only.

The geological–geochemical investigations aimed at the origin of the arsenic-bearing waters, and their results published in the scientific literature were restricted both in space and time. As the amount of analysis data was limited, in spite of valuable results some contradictions occurred as well.

The key-question of the origin of these waters remained unsolved; why did the biggest anomaly of arsenic content ever described in scientific publications from drinking water develop just in Hungary, and precisely in the Alföld region of the national territorry?

Because of the many unanswered questions about the genetic conditions we deemed it necessary to elaborate a new genetic model. We had to reconsider the existing patchwork of data on arsenic-bearing artesian waters and apply also the evidence in foreign publications. This model aimed to create an action plan for further research. The new conceptual model was based on the following considerations:

1. The former assumption concerning the source area of enriched arsenic content in the artesian waters (CSÁKI et al. 1983, SZEDERKÉNYI et al. 1990, ERDÉLYI 1990, 1991) must be modified. The Carpathian and Transsylvanian belt of ore-mineralized magmatites can not be regarded as the exclusive source of the arsenic in our domestic arsenic-bearing waters. The following facts must be taken into consideration:

— Arsenic-bearing artesian waters occur in sediments arriving not only from the Carpathian–Transsylvanian territory but also from source regions of entirely different character, i.e. from the catchment areas of the Danube, of the Dráva and Zagyva rivers.

— The average of the arsenic content differs only insignificantly in the various magmatites and sedimentary rocks. These slight differences can not be regarded as explanation for the differences of concentration in the secondary enrichments exceeding primary ones by orders of magnitude.

— Due to the diluting and averaging character of the processes of wheathering the presence of arsenic-rich hydrothermal formations in the catchment areas can not be regarded as determining factor.

2. The genetical model based on the supposed origin of the arsenic-bearing waters from great depth (SZEDERKÉNYI 1990) is in contradiction to the chemical composition of these waters especially with regard to the distribution of the anions (verbal information of I. HORVÁTH). The composition does not point to abyssal origin. Also, the distribution of the arsenic-bearing waters by depth does not support this genetic model.

From these considerations it can be deduced that the arsenic-bearing waters do not originate from great depths — i.e. from the basement, moreover their occurences can not be connected to well defined erosional areas. They may also be found in such regions of the country which are far from the Carpathian–Transsylvanian areas.

Regarding the mode of transportation of the arsenic two possibilitites are to be considered. Arsenic may be transported either in dissolved state or included in the the crystal lattice of the (mostly) silicate minerals occurring in the fine grained detrital material of source rocks. This form of the arsenic is not affected by surface processes; it may exceed the dissolved amount by 2–3 orders of magnitude. It is important to note that arsenic-bearing minerals which might be considered as sources of this element by their weathering and sedimentation were not found by micromineralogical investigations in Hungarian or Romanian (Transsylvanian) fluvial deposits of the Quaternary.

We have no evidence relative to the formation of arsenic-bearing waters by the interaction of rock and interstitial water. Even the character of the occurrences as it is determined by geographical setting, time of formation and facies gives rise to contradictions in every model based on purely mineralogical and geochemical ideas.

It is very probable that the arsenic accumulated in artesian waters originates from an external source and enters into the sedimentary basin in dissolved state. A very convincing explanation for this assumption is furnished by the process of mobilization of the soluble arsenic content of sulphide minerals in the form of arsenate anions freed by oxidative surface weathering in the source area.

Indirect data indicate that subsequent to mobilization the arsenic enters into the area of sedimentation in very dilute solutions or by adsorption on the surface of humic colloids or colloidal Fe-hydroxides.

By taking into consideration the very low arsenic content (ranging 1–10 μg/l) of the surface waters it is clear that the formation of artesian waters having more than 50 μg/l arsenic content has to be the result of a geochemical process, by which the considerable accumulation takes place.

In the given geological environment, considering also the possibilities of accumulation known from published geochemical references the enrichment of arsenic by adsorption on the surface of colloidal oxi-hydroxides of iron (HEM 1977) can be singled out as the most likely genetical process responsible for this phenomenon.

The formation of iron oxi-hydroxides is well known in Quaternary fluvial flood plain and paludal formations (like the bog-iron ores and variegated clays) of Hungary. The possibility of the arsenic-enrichment bound to crystalline and colloidal ferric oxi-hydroxides is supported by our analytical results which indicate that the arsenic (As) content of the domestic bog-iron ores exceeds 1000 ppm regardless of the site of occurrence. The measure of enrichment by adsorption is characterized by the fact, that the arsenic content of the investigated bog-iron ores exceeds three times the respective clark value of rocks and five-six times the average value given for waters by the scientific literature.

The enrichment of arsenic on colloids of Fe hydroxides can occur in the sediments of any flood-plain, irrespective of the geological environment and of the arsenic content in the surface waters of the given area.

It follows from the geochemical character of the arsenic, that following burial the colloid ferric oxi-hydroxide minerals are beginning to be decomposed by reducing diagenic processes. The soluble arsenic freed from the adsorptive bond enters into the interstitial water. The redox limits of the remobilization of the arsenic, i.e. the limits of the formation of arsenic-bearing pore waters are well known. The upper limit coincides with the ferric/ferroan boundary: it is indicated by the formation of arsenite anion and minerals of Fe^2 (ankerite, siderite). The lower limit is marked by the appearance of sulphide anions and sulphide minerals due to the increased intensity of the reduction.

According to these characteristics the remobilization process of the arsenic i.e. the formation of arsenic-bearing artesian waters takes place during early diagenesis in a narrow redox domain of transitional and moderately reductive character. Bacterial activity and the organic matter content of the system are the most important factors in this process. Proof for this is the correlation between arsenic, methane, iron, manganese and ammonia content of the waters. The genetic model outlined here answers also the following questions:

— Why are the arsenic-bearing waters bound only to the most recent Quaternary sediments which are in early stage of diagenesis, and why is arsenic missing from older formations which went through a complete diagenesis?

— Why do we find in Hungary the greatest occurrence of the arsenic-bearing artesian water known in the world? Has this to do with having very thick Quaternary sequences or other peculiar geological conditions?

So far we have completed only the first steps in the study of arsenic-bearing artesian waters; still many problems are left to be solved. It seems that the most important one of them is whether the arsenic-bearing waters are autochtonous. This problem has not been investigated yet. The ^{14}C isotope dating carried out by J. Deák (in Rónai 1985) indicates an age of approximately 30 thousand years. From these data the following conclusions can be drawn:

— The age of arsenic-bearing artesian waters differs from that of aquifer; thus the waters were not formed in the area of their present occurrence.

— The areal extent of this type of artesian waters is strongly influenced by the systems of underground flow.

Further isotope geochemical investigations are needed to bring the question of the provenance to the waters to a well founded conclusion and to indicate the best direction for further work. Answering these questions allows setting the priorities of studies of rock-and-water interaction and the regional ground water flow systems.

Apparently there are still considerable deficiences of our present knowledge. We know already that arsenic-bearing artesian waters can occur also in regions of the country which had been deemed free of this phenomenon up to now — but only scattered investigations were done in these areas. We find important targets for further research in the valleys of the rivers filled by Quaternary formations. Within these units the protected bases of the communal water supply (like the Dráva-valley, the alluvial fan of the Maros river and the Szigetköz–Hanság region) are of primary importance. The regions of extant and drained bogs, swamps and protected flood plains are fields for further investigation as well.

At present we have little data about the arsenic contained in domestic groundwaters and in fluvial, floodplain and paludal formations which are older than the Quaternary.

Acknowledgement

I express my thanks to the management of the OKI for allowing access to the data of the public health organizations on the arsenic content of drinking waters, also to Mr. Alán Péter and Mr. Mihály Csanádi, and to their colleagues Mr. Gábor Bozsai and Mr. Zoltán Kárpáti for their help. I also owe thanks to Mr. István Horváth for his help in the development of the data processing and GIS system.

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A MAGYARORSZÁGI ARZÉNES RÉTEGVIZEK FÖLDTANI–GEOKÉMIAI KÖRNYEZETE ÉS LEHETSÉGES GENETIKÁJA

CSALAGOVITS IMRE

Magyar Állami Földtani Intézet, 1143 Budapest, Stefánia út 14.

T á r g y s z a v a k : geokémia, rétegvizek, arzén tartalom, Nagyalföld

ETO: 550.4(439.14) 556.33(439.14) 549.24:556.33(439.14)

Közegészségügyi szakemberek 1981/82-ben ismerték és mérték fel a rétegvíz eredetű alföldi közüzemi ivóvizek rendellenesen magas arzéntartalmát. A rétegvizek földtani–geokémiai folyamatok hatására kialakult, az egészségügyi határértéket meghaladó arzéntartalma nagy területen mutatható ki, és közel félmillió fogyasztót érint. A sürgősen megoldandó közegészségügyi–vízellátási gondok nagyobb részét — sok milliárdos ráfordítással — azóta felszámolták, de a hosszútávú megoldás kialakítása a jövő feladata.

Az 1993-ban indult vízgeokémiai vizsgálatok célja a továbblépés hiányzó, de nélkülözhetetlen ismereti feltételeinek megteremtése. A dolgozat az 1993. évben elért első eredményeket foglalja össze.

1. A 6500 vízkút adatait tartalmazó adatbázis és térinformatikai rendszer révén országosan újravizsgáltuk és térképen ábrázoltuk az arzénes vizek — az addig ismertnél jóval jelentősebb — térbeli elterjedését.

2. Az arzénkoncentrációk kétmaximumos lognormál gyakorisági eloszlása alapján megállapítottuk, hogy az arzén nagymértékű felhalmozódása egy jól elkülöníthető, sajátságos arzéndúsító geokémiai folyamat eredménye.

3. Megállapítottuk, hogy az arzénes vizek negyedidőszaki földtani–geokémiai környezetben, a folyóvízi–ártéri–mocsári üledékek korai diagenetikus átalakulási folyamatai során, több szakaszban képződtek. Bizonyítható, hogy az arzén felhalmozódása főként a kolloid Fe-oxihidroxidok felületén lejátszódott adszorpciós, remobilizációja pedig a betemetődést követő, bakteriális–redukciós folyamatokkal hozható kapcsolatba.

4. Az új eredmények birtokában kijelöltük az arzénes vizek megjelenésének lehetséges területeit és a továbbkutatás célszerű irányait.

ANN. REP. OF THE GEOLOGICAL INSTITUTE OF HUNGARY, 1992–1993/II: 93–102 (1999)

A DETAILED SOIL-GEOCHEMICAL SURVEY FOR GOLD CONCENTRATIONS IN THE AREA BETWEEN FÜZÉRKAJATA AND VILYVITÁNY, THE TOKAJ RANGE, NE HUNGARY

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Manuscript received in 1994.

Keywords: geochemical method, soil, gold, Tokaj Range, Hungary, ore deposit, hydrothermal process, mineralization

UDC: 550.4(234.373.3/.5Tokaj) 553.411(234.373.3/.5Tokaj)

A detailed geochemical survey based on soil sampling was carried out in an area of 13 sq.km between the villages Füzérkajata, Füzérradvány, Vilyvitány and the Slovakian border through a Hungarian–Slovak geological co-operation. From the B horizon of soil, a total of 1382 samples were taken on a grid of 200 m × 40 m. Analyses were done by OES, AAS and ICP methods. Using the use of anomalous values determined from cumulative frequency curves three areas of considerable anomaly were outlined, which represented strong concentrations of silver, arsenic, antimony and mercury, too. The appearance of a primary dispersion zone serving as a source of anomalies was governed by tectonics. Their direction deviates characteristically from that of the mean strike of the dyke-quartzites of Korom-hegy, and corresponds to the NNW-SSE trending strike of the polymict breccias containing fragments of quartzitic, siliceous and limonitic rocks. Element concentrations depend on the depth of erosion. Trial pits confirmed the presence of gold-bearing rock near the surface. Neither the quality, nor the areal and vertical extent of the ore body are sufficiently known. Further exploration is warranted to determine the economic potential of the mineralisation.

A small-scale geological survey covering the entire area of the Tokaj Range commenced in 1989. During the survey, a new area of anomaly was outlined, outside the zone of well-known medieval workings. The association of elements (Au, Ag, As, Sb and Hg) is indicative of low-temperature hydrothermal processes. One of the prospects might be the zone lying between Füzérkajata, Füzérradvány, Vilyvitány and the Slovak border. In the meantime, we have been informed (HORVÁTH, ÓDOR 1990, 1991) that in the adjacent Slovak territory, starting from 1980, systematic geophysical, geochemical and geological surveys have been conducted by Geologický prieskum — Geological Exploration Company — Spišská Nová Ves. By means of panning and other methods, the Slovaks have found anomalies which seem to be analogous to the precious metal mineralisations and shows observed in the Prešov Range and elsewhere. As a follow up, a geochemical survey by detailed soil sampling was launched in the frontier region, through a Hungarian–Slovak co-operation.

Geological make-up; former studies

The mapping in the '60s and the search for "precious" clay deposits have contributed greatly to the knowledge of the geological setting (MÁTYÁS 1971, 1978, ILKEYNÉ PERLAKI, PENTELÉNYI 1968, PENTELÉNYI 1969, PENTELÉNYI, ILKEYNÉ PERLAKI 1968). Exploratory drilling was done at Korom-hegy, and the deeper bedrock was reached in borehole Füzérkajata–2 drilled nearby.

The oldest rocks known in the region are Lower Paleozoic gneiss and phyllite, which have surface outcrops in the east (Vilyvitány–Felsőregmec) and are found below the Badenian-Sarmatian volcano-sedimentary complex in the drilled section Füzérkajata–2. The overlying sequence of a few hundred metres is composed of clay, tuffite, tuff, andesite and dacite (MÁTYÁS 1971; ILKEYNÉ PERLAKI, PENTELÉNYI 1968).

In the Korom-hegy area Upper Sarmatian rhyolite tuff and tuffite are found on the surface, which are partly silicified or clay-mineralized. In the light of drilling data, the volcanic tuff complex shows a threefold division. At the bottom there are siliceous, kaolinitic-illitic tuffs, at the top, siliceous-kaolinitic rhyolite tuff and quartzite, in a combined thickness varying irregularly from 5 to 50 metres. Above this division, there is "precious" clay, sandy-pebbly illite and illitic tuffite; the thickness of the irregularly shaped "precious" clay lenses varies from 5 m to 30 m. The uppermost strata are composed of limnoquartzite, conglomerate and lacustrine micaceous clay in a thickness of 10–50 metres. The lake quartzite is made largely of α-quartz. Barite, pyrite and jarosite have also been identified therein.

In the north, the hill Bába-hegy is built of rhyodacite. The rocks of the Korom-hegy area are recorded as having been altered by alkaline metasomatism and alunitization

(MÁTYÁS 1971, GYARMATI 1981). During the search for illite between 1966 and 1969, considerable amounts of K_2O (max. 13–14%) and of SO_3 (max. 2.5%) were found in "precious" clays. Anomalous values of base metal content were recorded from the borehole Füzérradvány 18 (MÁTYÁS 1971), where As, Pb, Zn, and Co also show enrichment in veinlets of siliceous clay and pyrite.

In limnoquartzites around Füzérradvány, an increase of As and Hg contents was reported by I. VETŐ (1971), who made reference to the fact that this association of elements is characteristic of epithermal gold deposits. Likewise, an enrichment of As, Sb and Pb in limnoquartzites was found in the slope debris near the illite mine by S. SZAKÁLL (1989).

On the basis of a parallel study of samples produced by panning or taken from stream sediments, soil and rock detritus, geologists taking part in the small-scale geochemical survey have declared this sub-area to be an exploration target for precious metal mineralisation.

Sampling, sample preparation and data processing

Field sample collection and sample preparation

In 1990, in agreement with Slovak colleagues, the Korom-hegy and Bába-hegy area of 13 sq.km was sampled on a grid of 200 m × 40 m (Fig. 1). After removing topsoil, samples were taken from a depth of 15 to 30 centimetres representing soil horizon B. In the original wet state, each individual sample weighed c. 1 kg. The inclusion of macroscopic, recognizable, organic matter was avoided, however, sometimes a few small rock fragments might have remained in the sample. Sections set up by Hungarians and Slovaks meet at the national border. In all, 1382 samples were collected.

Sample preparation, analytical methods

First the material was dried at 40 °C. Then after grinding the material was passed through a 60 µm sieve, and the residue was analysed. The semi-quantitative OES method was found suitable for determining 22 elements. After treating with aqua regia (nitrohydrochloric acid), gold was analysed in graphite furnace. The cold-steam method was used for the analysis of mercury, and hydride technique for that of arsenic and antimony.

Control test

In an earlier publication relating our investigations in the scope of the small scale survey we have already discussed the type and degree of analytical errors (HORVÁTH et al. 1992). The conclusions of the 1992 paper equally apply to our present study. Of the elements analysed by OES

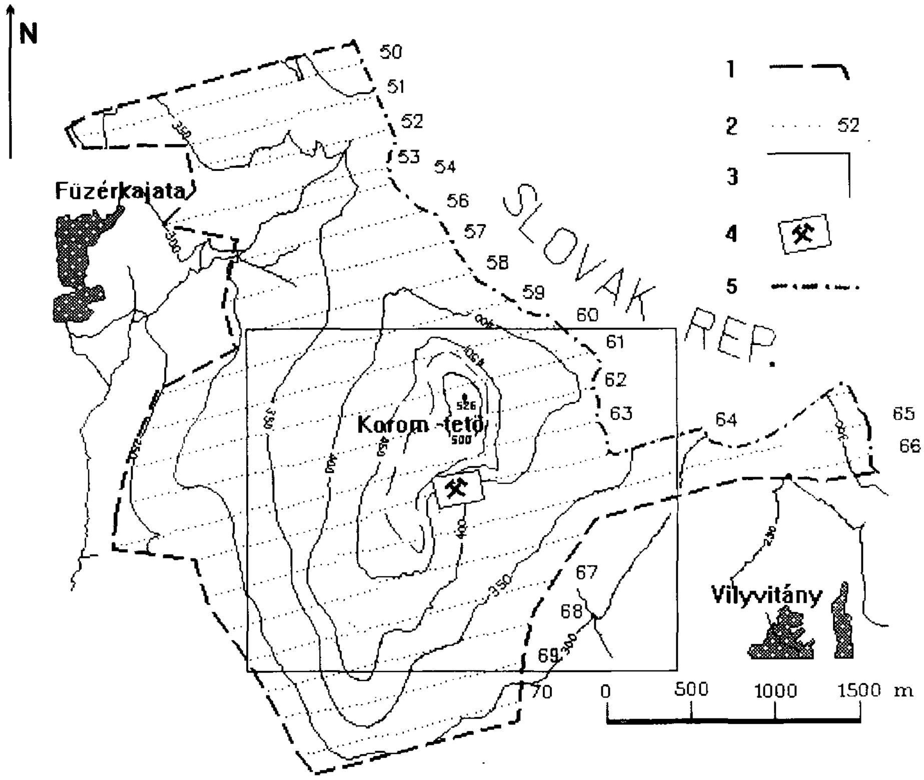

Fig. 1. Map of the sampling area

1. Boundary of the area surveyed, 2. Sampling points with section numbers, 3. Area of the generalized anomaly map (see Fig. 8), 4. Illite mine at Füzérradvány, 5. National border

1. ábra. A mintavételi terület tényanyagtérképe

1. A felvételi terület határa, 2. Mintavételi helyek a szelvények számával, 3. Az öszevont anomáliatérkép (8. ábra) területe, 4. A füzérradványi illitbánya, 5. Országhatár

method, non-systematic errors in determining B, Ba, Co, Cr, Cu, Ga, Ni, Pb, Sr, V, Y and Zr are all within acceptable limits, whereas Mo, Sb, Sn and Zn cannot be evaluated because they are so scarce they stay under the detection limit. The systematic error is significant, with the exception of B, Pb and V. Analyses of Ag become uncertain in the anomalous range of concentration (>10 g per t). As for the elements analysed by AAS and ICP methods, here both systematic and accidental errors are admissible.

Methods of data processing

Analytical data were processed by the SPSS PC+ statistical package using IBM compatible PCs. As an estimate of the expected value, we invariably used the median, instead of the arithmetic average. Rank correlation methods are considered to be most suitable to analyse correlations between component concentrations with irregular distribution (STEINER 1990). The standard program packages that are used by the Geological Institute of Hungary, however, calculate the Spearman and Kendall coefficients incorrectly (FÜGEDI 1998, in this volume). This problem restricted the uses of multivariate techniques.

Geochemical characteristics

Persistent in the literature is the illogical but empirically supported conception that the main components show a normal distribution. Examining the reason for this phenomenon, (SMYSLOV et al. 1979), came to the conclusion that the error of the analytical methods is comparable to the extent of natural variability, and the distribution is in practice controlled by the nature of the error. Since the accidental error of the routine method of (semi-quantitative) optical spectral analysis is multiplicative, components determined in this way have apparently a lognormal distribution. Quantitative analyses give a more genuine picture, independent of the type of analytical error. Regular (normal, lognormal etc.) distributions can be dealt with in the quasi-equilibrium state only.

According to the expectations outlined above, the distributions of Ba, (Be), Co, Cr, Ga, (Mo), Sr, V and Y are nearly lognormal. The irregular frequency curves of Ni and Zr are related to and explained by dissimilar background, whereas the abnormalities of B may be attributed to post-volcanic processes.

The adopted sampling method is not suited to the precise separation of the background and the anomalous field. Lithologically, the background is very heterogeneous, so for example, water transmissivity is very different in tuffites and in quartzites. Each sample reflects a specific vertical zone. Detrital materials move downwards and get significantly mixed. Owing to these factors acting together, for the majority of elements accumulating during mineralisation processes we obtain long protracted histograms of strongly positive skewness instead of separate frequency peaks (Fig. 2). Fortunately, for some reason, the selection of the threshold values for contrasting geochemical anomalies does not much spoil or improve the results of the method. Therefore we have adopted a mechanical solution, which helps representation on maps, and is accepted international practice. The 95–100% and 75–90% probability ranges of the cumulative frequency curve have been considered strong and weak anomalies, respectively (Table 1). An exception has been made for silver only; its anomalous concentrations appear in the form of an independent frequency maximum.

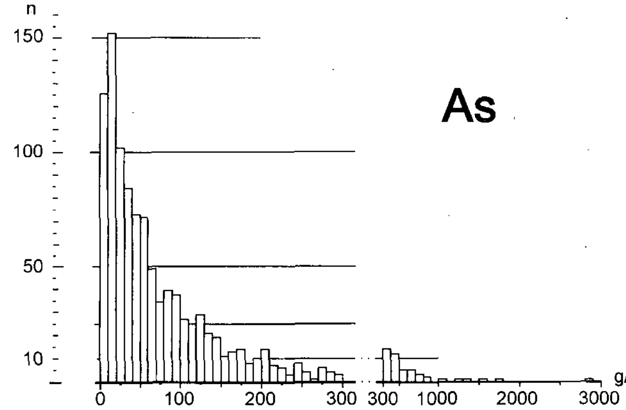

Fig. 2. Frequency curve of As concentrations plotted from the analytical data of all samples

2. ábra. Az As-koncentrációk gyakorisági görbéje az összes minta alapján

Table 1 — 1. táblázat

Limit values determined on cumulative frequency curves (g/t)
A kumulatív gyakorisági görbék alapján megvont határértékek (g/t)

	Low value	Higher value	Weak	Strong
			anomalies	
Au	<0.003	0.008	0.017	0.029
Ag		0.6	1.0	1.6
Hg	<0.18	0.34	0.69	1.08
As	<47	107	200	292
Sb	< 4	9	24	41

The correctness, or rather, acceptability of the selection is indicated by the fact that preferential sampling points show an interpretable grouping. For each element separately, definite anomaly patches became distinct, and similarly, when viewing them in conjunction a well-interpretable picture took shape.

Consequently, the distinction of background and anomalous fields is feasible, however, the role of subjective interpretation cannot be ignored. Nevertheless, the proportion of the samples displaying unequivocally anomalous concentrations does not exceed 20%, with only the exception of arsenic. As the median is fairly robust even in skewed distributions, and it does not involve serious error if we accept the median as an estimate of the background concentration, based on all the samples with a reduction by 10%. For the expected background value of As, a frequency peak of 10 g/t may be a relatively correct estimate.

Another problem might arise from the fact that rocks are poorly exposed here, so samples were taken from soils instead of solid rock. Therefore our data are related to secondary distribution haloes, and not to primary ones. However, from a large number of studies made in the former Soviet Union (by IMGRE Institute) it has been concluded that despite certain differences being present in the absolute values of concentration, the element spectra of primary and secondary anomalies are closely related.

Owing to the mixed types of distributions, the degree of variability can be estimated correctly neither in the case of background fields nor of the anomalous fields.

The correlation relationships of background-distributional elements are influenced by many factors (lithological make-up, systematic error of the analytical method, soil-forming processes, the homogeneity of sampling, etc.), so they are not of ore-geological importance, or their significance is merely subordinate. When comparing variables of other than normal distribution, calculation of the correlation coefficient is, a priori, a likely source of distortion (positive systematic error), still not mentioning problems in the determination of Spearman's rank-correlation coefficient. In some extreme cases even the signs of the two coefficients are different. Thus no attention was paid to their interpretation, even if their values were determined (HORVÁTH et al. 1992).

We were primarily interested in elements of anomalous distribution (Au, Hg, As and Sb) examined quantitatively. Their correlation is unequivocally positive, at a significance level of 99.9999 per cent, indicating that their mobilization and accumulation must have taken place during the same geological process.

According to the Kendall coefficient and based upon a linearity test As and Sb seem to have been most closely correlated, followed by the As–Hg and then by the Sb–Hg pairs. Looking at the relationship between gold and the above-mentioned three elements (As>Hg>Sb), it becomes clear that although the highest gold concentrations are almost invariably associated with high values of As, Sb and Hg, anomalies of the latter mobile elements are also present in media of lower Au contents.

Designation of anomaly areas

On the map, at the east, south and west of the top of the hill Korom-hegy, some areas can be distinguished which are most likely to have been indicated as Au anomaly zones of stronger significance, with the accumulations of silver, arsenic, antimony and mercury (Figs. 3 to 8). At the south-eastern corner of the field concerned, values of Hg, Au and As are indicative of another anomaly area, which has also been confirmed by geophysical measurements (KOMORA, OKAL' 1992). (For the sake of clarity, some solitary "patches" plotted on the basis of a single sampling to each, have been left out. Values of gold and silver, however, are marked without exception).

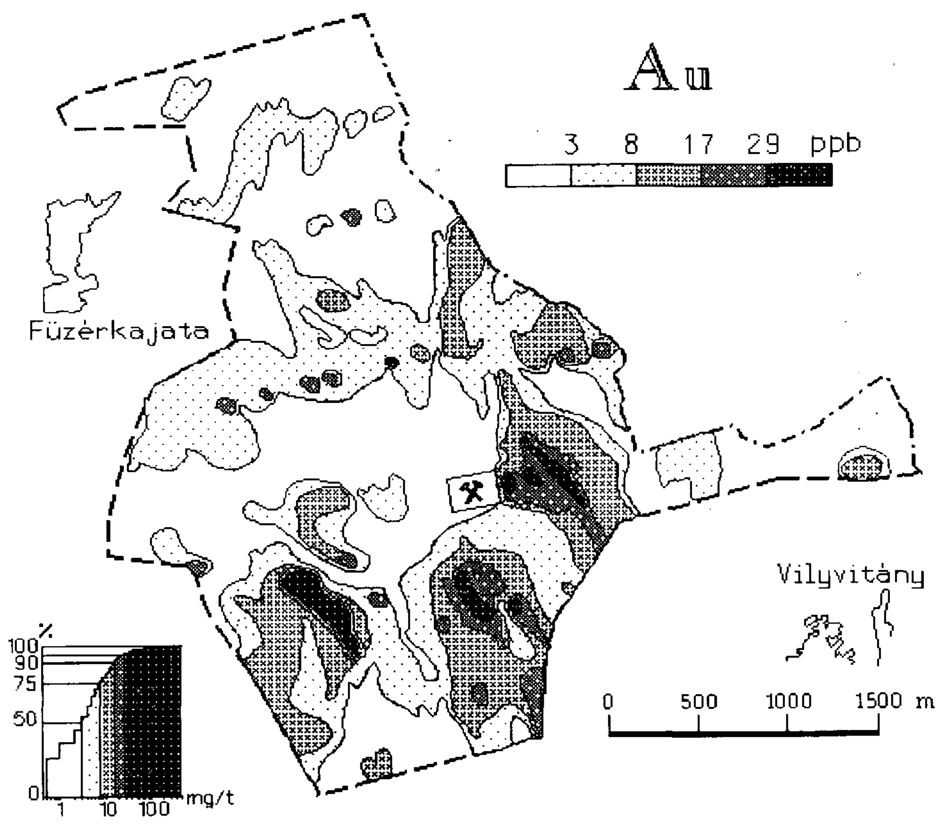

Fig. 3. Anomalies and cumulative frequency curves of Au

3. ábra. Az Au anomáliái és kumulatív gyakorisági görbéje

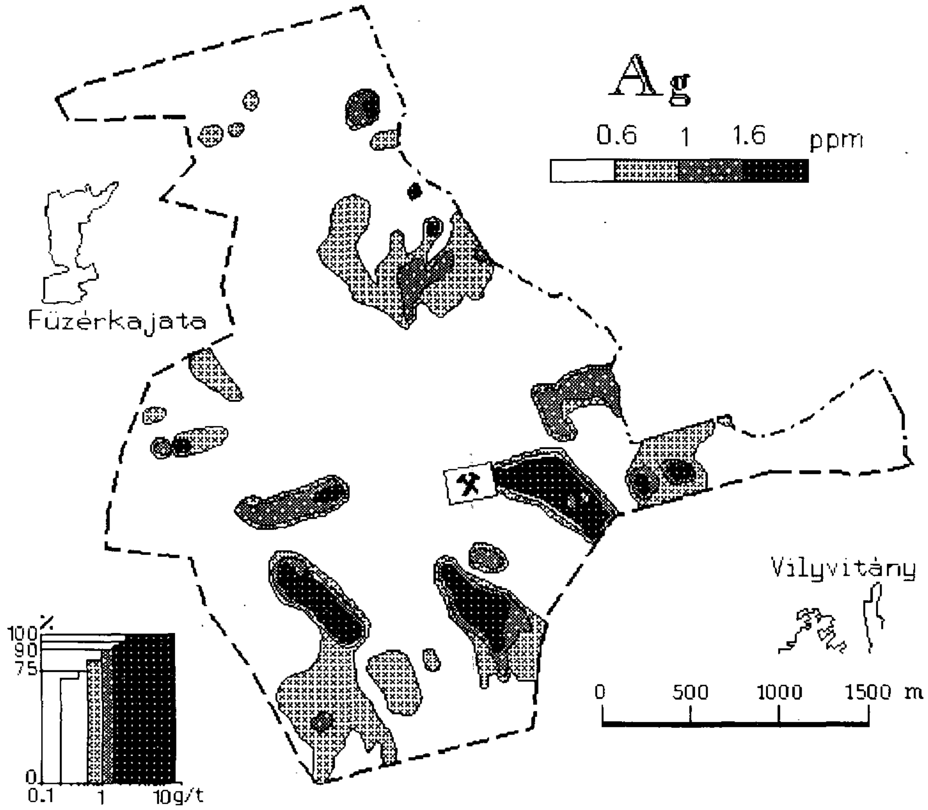

Fig. 4. Anomalies and cumulative frequency curves of Ag

4. ábra. Az Ag anomáliái és kumulatív gyakorisági görbéje

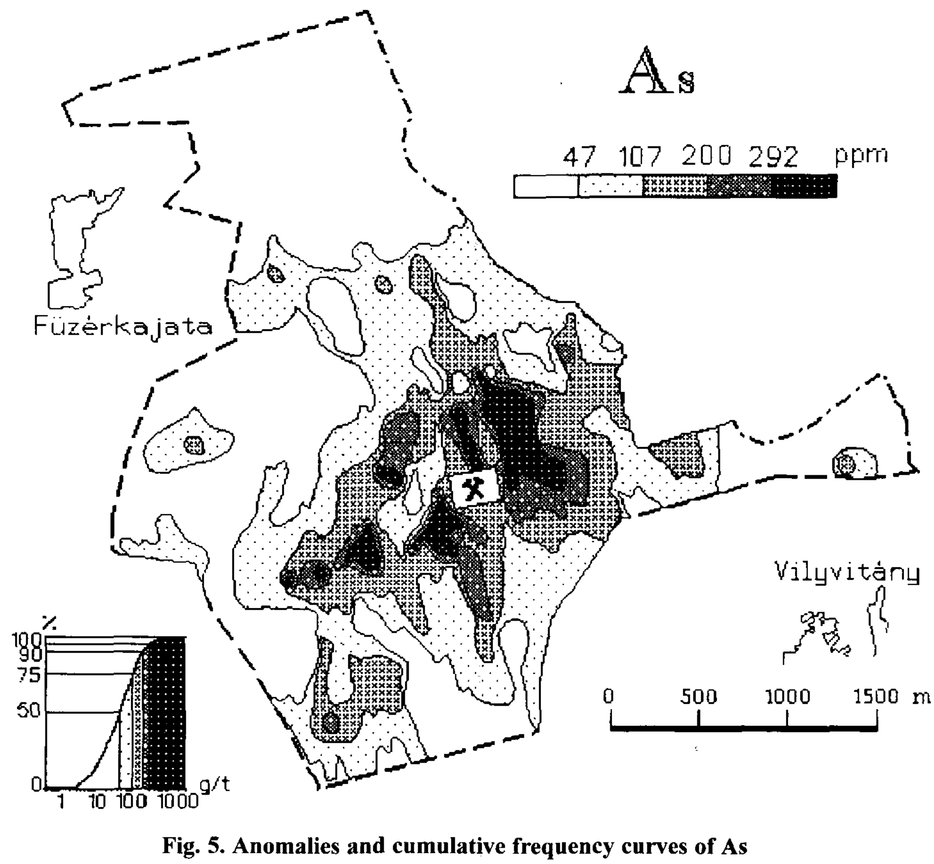

Fig. 5. Anomalies and cumulative frequency curves of As

5. ábra. Az As anomáliái és kumulatív gyakorisági görbéje

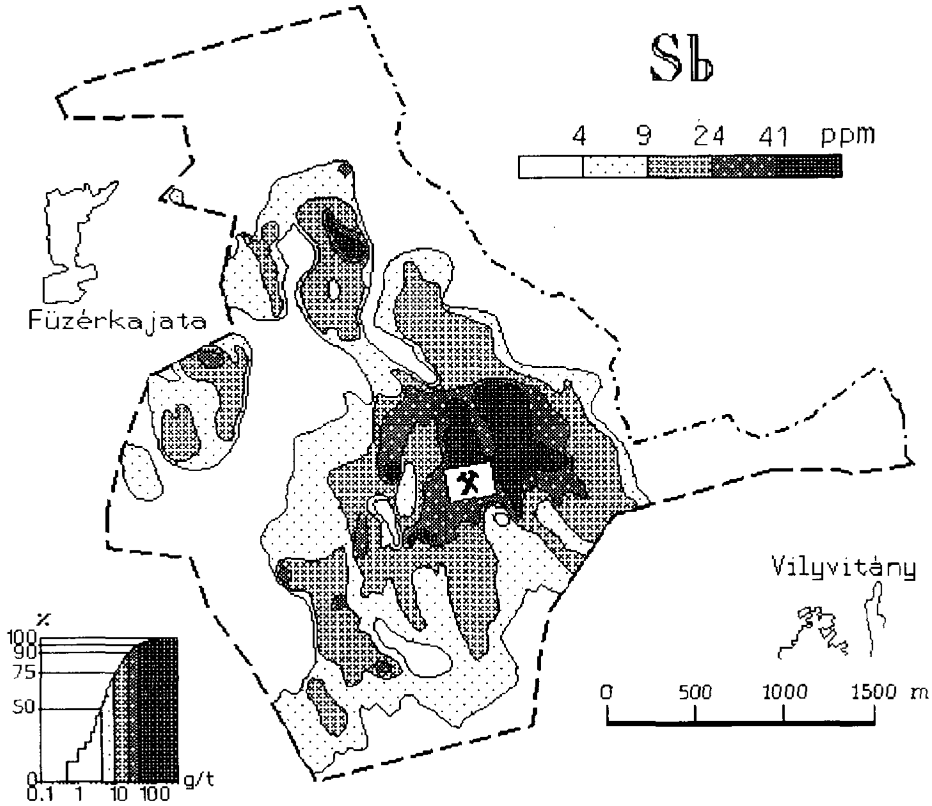

Fig. 6. Anomalies and cumulative frequency curves of Sb

6. ábra. Az Sb anomáliái és kumulatív gyakorisági görbéje

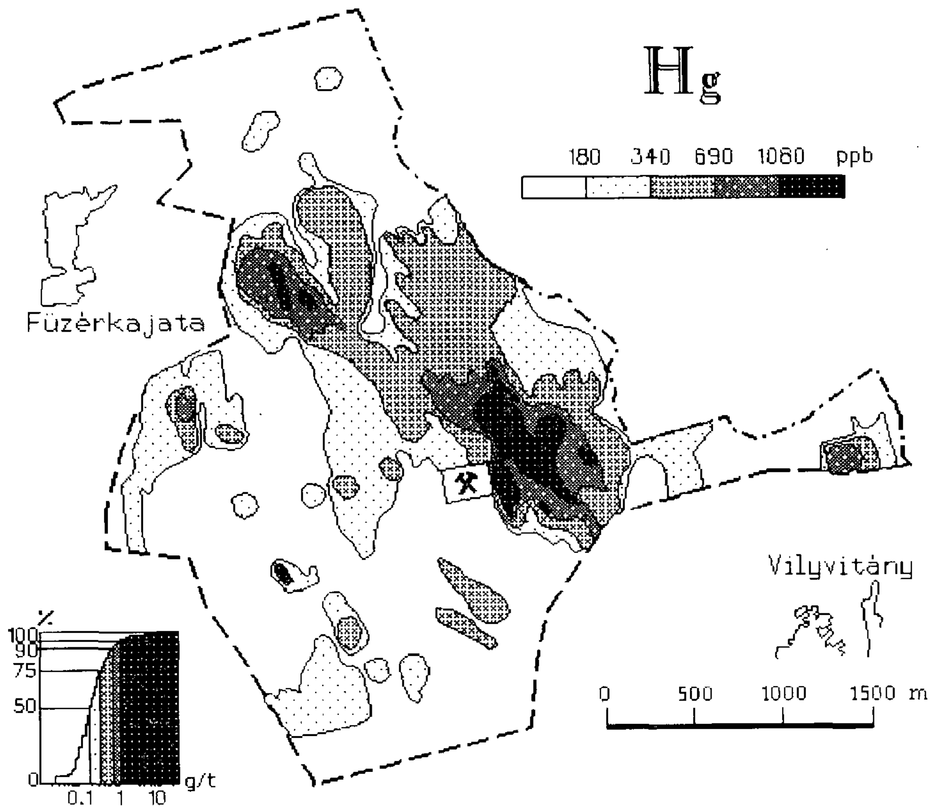

Fig. 7. Anomalies and cumulative frequency curves of Hg

7. ábra. A Hg anomáliái és kumulatív gyakorisági görbéje

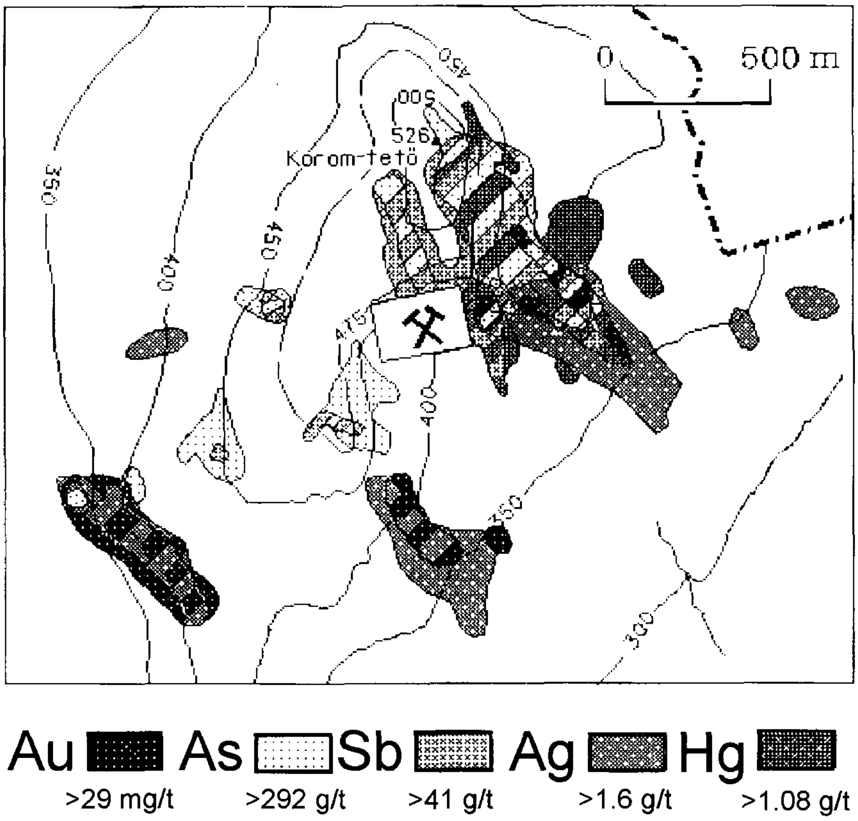

Fig. 8. Generalized anomaly map showing the central part of the survey area

8. ábra. Összevont anomáliatérkép a felvételi terület központi részéről

In spite of the dissimilar shape of their contours, anomalies of all the five elements are elongated in a NW–SE striking line, which is clearly outlined. This is independent of the mode of contour plotting, the variations in element mobility and downward motions of the medium sampled. The strike makes it quite clear that the primary dispersion haloes, representing the source of the elements, have been pre-determined by tectonics. Their direction characteristically deviates from that of the average of the NNE–SSW striking dyke-quartzites of Korom-hegy, but coincides with the NNW–SSE strike of the quartzitic–siliceous–limonitic polymict breccias discovered in the area after the close of our investigations (a verbal communication from T. ZELENKA).

The coincidence of the anomalies of gold and its associated elements was examined in three anomaly areas. The strength of the connections is nearly identical with that of the correlations established for the entire area. We can see the markedly related movement of Ag–Sb from the results — a geochemical commonplace. After Ag–Sb, the connections between Au–Ag and Sb–Hg are the most marked.

Figs. 3 to 8 show that anomalies of all the five elements appear only in the eastern part of the area, with some overlap. On the other hand, the high values of As–Sb–Hg stretch northwestwards beyond the Au–Ag anomalies, towards the somewhat higher elevations of the land surface. In the southern zone, the Au–Ag association is slightly separated in space from As–Sb. The detachment of Au–Ag from As–Sb–Hg is also marked in the western area. In the western zone there are fewer extreme values of As–Sb–Hg than in the east.

The above mentioned facts undoubtedly reflect features of the primary distribution indicating the level at which the primary dispersion halo became exposed by erosion. Temperature conditions of the metalliferous solutions (passing from higher to lower temperatures) are shown by the parallel spatial appearance of Au-Ag—Sb-Hg—Hg concentrations. Around Korom-hegy, base metal anomalies characteristic of the root zone of such ores are absent. They are thought to have been situated in deeper horizons.

Averages of the highly anomalous values demonstrate the contrasts of the three anomaly groups (Table 2).

Au anomalies are mainly present south of the hilltop of Korom-hegy, as attached principally to less steep-sided land surface forms, indicating that the primary dispersion halo i.e. their provenance site may have been made, at least partly, of un-silicified rocks.

Table 2 — 2. táblázat

Averages of the highly anomalous values according to anomaly groups

Az erősen anomális értékek átlagai anomália-csoportonként

Anomaly group:	Eastern	Southern	Western
Anomália csoport:	K-i	D-i	Ny-i
Au (ppb)	77	60	114
Ag (ppm)	3.0	2.4	3.1
As (ppm)	704	451	534
Sb (ppm)	112	70	47
Hg (ppm)	3.6	1.1	2.0

The interpretation of anomalies

The anomalies of Korom-hegy are believed to be products of two, non-simultaneous geological events. The older event was the emergence of thermal water activity related to acid vulcanism, before the intrusion of andesite took place during the younger event.

In the Zlatá Baňa area, Slovakia (DIVINEC et al. 1988) and in the vicinity of Berehove (Zakarpatya, western Ukraine), Au and Hg deposits are related to subvolcanic andesites and diorites. The rocks of a small andesite body and those of the other andesitic occurrences in the region (Pajna-domb, Vilyvitány) are fresh i.e. not altered by hydrothermal process.

In the past 10–15 years, precious metal mineralisations of hydrothermal origin were intensively explored. At present, they are mined in a number of places including Japan (EIJI, MASAHIRO 1991), Papua New Guinea (SILLITOE et al. 1984), California (HOLLISTER et al. 1992) and New Zealand (HEDENQUIST, HENLY 1985).

According to B. R. BERGER (1985) a characteristic vertical zonality comes into existence near thermal springs. At the top (surface) there are sedimentary deposits with erratically distributed Ag, As, Au, Hg and Sb enrichments. Downward it follows a thick, silicified horizon with brecciated portion at the base. The latter is underlain by fissured and veined rock (stockwerk). From the fissured zone up to the ground surface, in the entire series there are breccias produced by hydro-explosion. Workable ore minerals may be present in the cemented breccias (in the breccias of hydro-explosion and in the lower portion of the siliceous zone), and in stockwerk. Characteristic minerals and element associations of the precious ore mineralisation vary with the change of rock zones. At the top, silicification and an enrichment of As, Au, Ag, Hg and Sb are common, and rarely, native sulphur may also occur. In the siliceous and stockwerk-type zones Au, Ag, As, Sb and Tl are enriched. Diagenesis produced kaolinite, alunite, silica and jarosite. Segregations of silica and Cu–Pb–Zn–Au–Ag sulphides appear in the root zone.

The hydrothermal origin of the Korom-hegy anomalies is verified by the conclusions of geological mapping and mining exploration. Quartzites uncovered by erosion action, formed in a thickness of 1 to 1.5 m, range across the eastern slopes of Korom-hegy, striking NNE–SSW. Siliceous sinter deposited by hot springs is missing here owing to erosion. The sequence is as follows: siliceous rhyolite tuff–quartzite (and lake sediments)–"precious" clay (sand, gravel)–siliceous rhyolite tuff (tuffaceous rock, quartzite) indicating a varied intensity in the welling up of hot spring. The layout and extent of the Korom-hegy anomalies is governed mainly by element contents of the source rock, and to a minor extent by the hypergenetic mobility (solubility) of the different elements, as observable on the mono-elemental distribution maps (Figs. 3 to 7). Au anomalies are derivable mainly from soft rocks easily affected by weathering, which are liable to decomposition resulting in soil formation. Gold is liberated from these in the course of weathering, and accumulates in the soil. Siliceous rocks are transported a long way before braking down, thus little of their gold content appears in the soil. Au anomalies surround the siliceous cap of the hilltop. Their source is in the rocks (clay, tuff, tuffite, kaolin) of the so-called deposit horizon with Au contents of 2 to 200 g/t. Major anomaly zones are 200–500 m long, 50–130 m wide, and they strike NNW–SSE. Dispersion "tongues" formed by slope movements of the soil are rarer, even in the zone of steep hillside slopes. In the eastern anomaly area situated east and west of the mine all of the elements are anomalous in concentration, which can probably be attributed to mineralisation formed along a rock dyke or fault.

Ore-forming processes have to be supplemented by geochemical traps to give rise to deposits of economic value, otherwise only zones of disseminated mineralisation develop. The rock sequence of Korom-hegy, made of alternating permeable and impervious beds, may have contain a mineral deposit. Only a detailed ore-geological surveying could answer this question.

Acknowledgement

The authors would like to express their gratitude to Dr. K. EGYÜD, former Vice Director of the Geologický prieskum — Geological Exploration Company — Spišská Nová Ves, Slovakia and to Dr. P. BAČO (Košice, Slovakia), who initiated the common geochemical survey along the international border and have participated therein. Thanks are due to Dr. T. ZELENKA for his critical and constructive reading of the manuscript.

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RÉSZLETEZŐ AU-KUTATÓ TALAJGEOKÉMIAI FELVÉTEL A FÜZÉRKAJATA ÉS VILYVITÁNY KÖZÖTTI TERÜLETEN (TOKAJI-HEGYSÉG)

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Tárgyszavak: geokémiai módszer, talaj, arany, Tokaji-hegység, Magyarország, érctelep, ásványképződés, hidrotermális folyamat

ETO: 550.4(234.373.3/.5Tokaj) 553.411(234.373.3/.5Tokaj)

A Füzérkajata, Füzérradvány, Vilyvitány és a szlovák határ közötti 13 km^2 területen a szlovák–magyar földtani együttműködés keretében részletező, talajmintázású geokémiai felvétel készült. A talaj B szintjéből 200 m × 40 m-es hálóban, összesen 1382 mintát gyűjtöttünk. Az elemzések OES, AAS és ICP módszerrel készültek. A kumulatív gyakorisági görbék alapján meghatározott anomális értékek segítségével három komolyabb Au-anomáliaterületet körvonalaztunk, amelyeket erős ezüst-, arzén- antimon- és higanydúsulások kísérnek. Az anomáliák forrásaként szolgáló elsődleges szóródási udvarok szerkezetileg meghatározottak. Irányuk karakterisztikusan eltér a Korom-hegyi telérkvarcitok átlagos csapásától, a kvarcitos kovás limonitos polimikt breccsák ÉÉNy–DDK-i csapásirányának felel meg. Az anomáliaterületek elemkoncentrációi jellegzetes különbségeket mutatnak, amelyek a primer eloszlási kép sajátosságait tükrözik, s jelzik a különböző eróziós feltártsági szinteket. A terület felszínközeli aranyércperspektívája megerősítést nyert, s bár az ércesedés minőségét, méretét, mélységbeli kiterjedését nem ismerjük, az eredmények alapján kijelölhetők a perspektivitást véglegesen tisztázó további ércföldtani kutatások.

ANN. REP. OF THE GEOLOGICAL INSTITUTE OF HUNGARY, 1992–1993/II: 103–109 (1999)

DISTRIBUTION OF NUTRIENT ELEMENTS IN SOILS OF THE SZARVAS PILOT AREA

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Manuscript received in 1994.

Keywords: soil, nutrient elements, pollution, Szarvas pilot area, Hungary

UDC: 631.42(439.175) 556.32:519.23(439.175) 504.064(439.175)

This paper discusses a study that has been undertaken as part of a project of developing new methods for agrochemical analysis. The paper focuses on the results of a multivariate statistical analysis aimed at the determination of distribution patterns of several nutrient elements in the soil indispensable for the growth of plants. Four geochemical zones have been selected in the uppermost 10 m of the profile, enabling us to study the relationship between the concentration of nutrient elements in the complex system soil — parent material — soil solution. We have also attempted to define mechanisms controlling the distribution of particular elements.

The analysis resulted in the selection of four populations of elements featuring correlations of various strength, in the four geochemical levels. A strong relationship between mobile compounds of heavy metals and the proportion of colloidal complexes in different zones of the soil profile has been reaffirmed with some specific implications due to the application of 2M HNO_3 as agent of extraction. Principal component analysis proved to be a powerful tool in handling this issue.

Introduction

Given the geological setting of Hungary, the agricultural sector plays a major role in the national economy. Consequently, agrochemical studies have a crucial importance in improving agricultural production. Therefore, in the late 1970s the Department of Agrogeology of the Geological Institute of Hungary launched an extensive project with the objective of developing a standard vegetation-oriented method to study the relationship between the availability of nutrients for plants and agrochemical conditions prevailing in the soil. This method, called BFK after its initiators (A. BARTHA, U. FÜGEDI, L. KUTI) represents a basically new approach by extending the inspection beyond the traditional 2-m-thick zone of the soil to the uppermost 10 m of the profile. It allows the analysis of the balance of nutrients in the complex system of soil — parent material— soil solution. The profiles studied are composed of loose sedimentary sequences giving rise to a soil layer suitable for agricultural practices.

The basic principle of selecting pilot areas was to cover all representative soil profile types occurring in Hungary. On the basis of previous investigations 4 subhorizontal agrochemical zones have been distinguished, revealing markedly distinct nutrient balances in the profile. These are as follows:

1. Traditional horizon A.
2. Zone of the fluctuation of ground-water above its hydrostatic level.
3. Zone of fluctuating ground-water below its hydrostatic level.
4. Zone permanently below the ground-water table.

Apart from elucidating the relationships between the availability of nutrient elements, one of the highest priorities of the recent investigation of the Szarvas pilot area was the determination of the mechanisms governing the elements' distribution.

Methods applied

Field-work in the approximately 64 sq.km large pilot area included the drilling of 94 10-m-deep, shallow boreholes with a spacing varying between 500 and 1000 metres. Soil samples were collected by horizon, according to the above described four agrochemical zones. In addition to defining the concentration of 21 elements, traditional methods have been applied for the determination of granulometric composition including clay content, as well as pH and lime content. 2M HNO_3 was chosen for the extraction of nutrient elements whose concentration in the resulting extracts was measured either by flame atomic absorption procedure or ICP-OES method. On the whole, ca. 9000 data values measured on 376 samples were available. It should be noted, however, that the application of nitrate acid as extractive agent complicates considerably the comparison of results with other pilot areas. According to some authors, this removes approximately 80% of total nutrients from soil samples.

Results and discussion

Univariate and multivariate statistical techniques have been applied to selected populations of elements showing significant correlation. Given the spacing of the boreholes, preliminary tests showed that none of the elements can be described by a regular spatial distribution. This introduces some ambiguity in the interpretation. Improving the interpretation for such uneven distribution pattern of elements would need a 50-100-m-dense drilling network, which is unlikely to be applied in regional soil surveys.

Fig. 1 displays the relationship between means of concentration in the four agrochemical levels on the one hand and that of the whole profile on the other hand. Four populations of elements can thus be selected, namely:

I — Al, Co, Cr, Cu, Fe, Ga, K, Li, Ni, Pb, V, Zn
II — Ba, Cd, Mn, P
III — Ca, Mg, Na, Sr
IV — Ti

The similar behaviour of each constituent in respective groups is easily recognizable. Elements of the first two classes accumulate primarily in the first horizon, rich in humus. They undergo a sharp decrease in the second level, then remain constant up to a depth of 10 m. On the contrary, the third population resides preferentially in the zone of fluctuating ground-water, whereas the humus layer as well as the zone permanently below the ground-water level are unfavourable for these. The distribution of titanium exhibits a specific behaviour. Its concentration increases gradually with depth. The variances of elements belonging to each groups also shows common features.

In order to confirm the above subdivision of particular elements to four populations by the monovariate statistical method and to reveal the physical and chemical mechanisms controlling their distribution, the whole set of data has been subjected to principal component analysis (PCA). It is a multivariate statistical method making use of the correlation between the particular variables of the whole population transforming the original set of variables (N) into new ones (n) and reducing thus their number to be taken into account. The transformed variables are called *principal components.* They are numbered from 1 to n. The orientation of the first principal component in the N dimensional space of the original population represents the direction of the largest variance of the system. The second principal component at right angle to the first one indicates the second largest variance etc. Generally, it can be stated that principal component analysis can be used efficiently only if the original set of variables correlate with each other to a certain degree while only the first 2–4 principal components are of importance for interpretation.

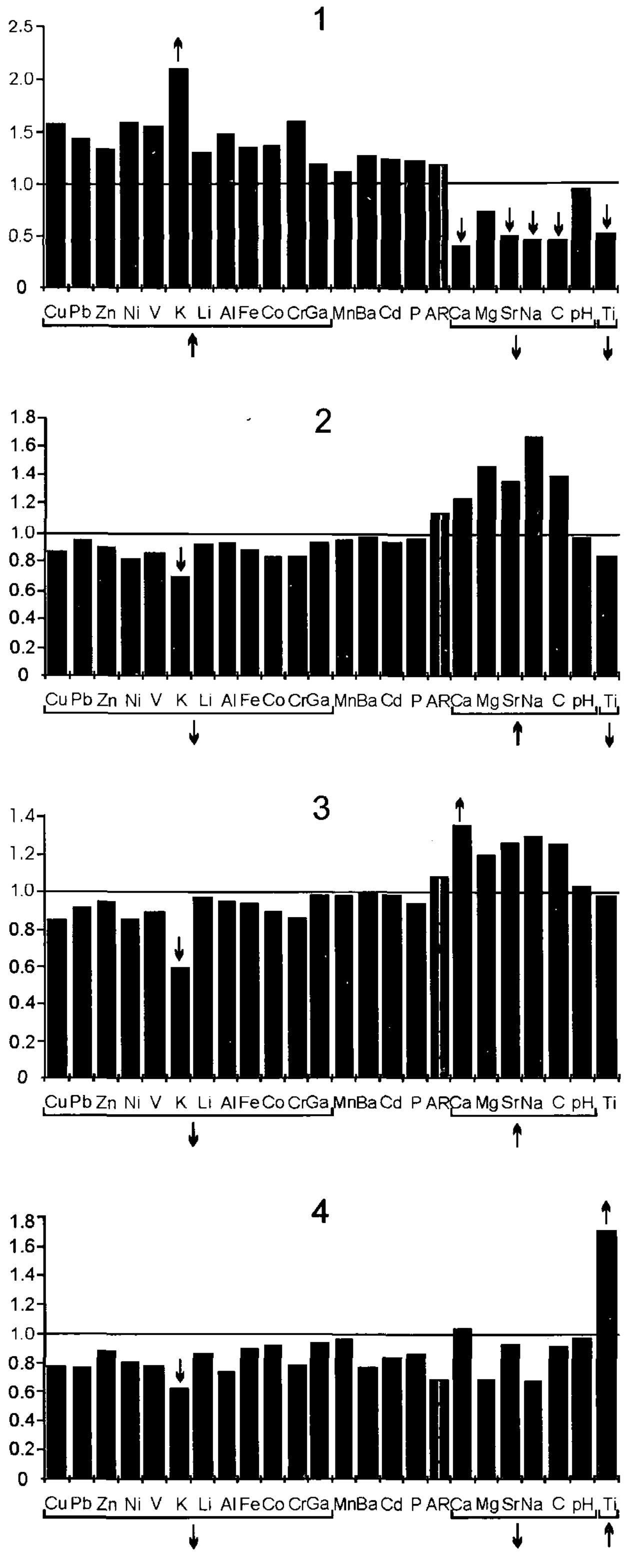

Fig. 1. Relationship between the means of concentrations of elements related to the 4 geochemical levels and that of the whole profile

1. First layer, 2. Second layer, 3. Third layer, 4. Fourth layer, ↓↑ Characteristic tendencies

1. ábra. Az elem-koncentráció 4 különböző geokémiai szintben mért átlagértékeinek és a teljes szelvényre vonatkozó átlagértékeknek a hányadosa

1. Első szint, 2. Második szint, 3. Harmadik szint, 4. Negyedik szint, ↓↑ Jellemző tendenciák

The others represent some background effects. The mentioned first 2–4 components classify the variables in the N dimensional space to specific groups upon the correlation existing between them. In this case, i.e. concerning the distribution of nutrient elements represented in the N dimensional space, the position of these groups is determined by the physical and chemical processes represented mathematically by the particular principal components that we try to interpret. There are a number of papers and studies devoted to principal component analysis, therefore we do not intend to go into more detail concerning the basic principles of this method.

The "circles of correlation" (principal component plots — Figs. 2, 3, 4) for the whole profile and for each of the four geochemical horizons prove the existence of the four clusters of elements identified by univariate methods. The members of the groups are somewhat scattered in different levels, nevertheless, the majority of them preserve their correlation. The first group is found at the right margin of circles all along the profile, whereas the third population undergoes a more considerable dispersion. Titanium occupies an isolated position but it is noticeably linked to depth.

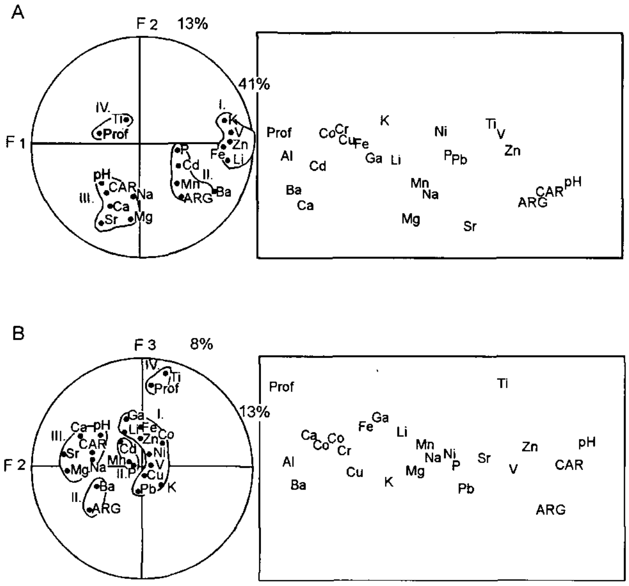

Fig. 2. "Circles of correlation"
A = The whole set of data — F1–F2, B = The whole set of data — F2–F3; I, II, III, IV. Populations of elements and factors differentiated

2. ábra. Korrelációs körök
A = A teljes adathalmazra vonatkozóan — F1–F2, B = A teljes adathalmazra vonatkozóan — F1–F3; I., II., III., IV. Elkülönített elempopulációk és paraméterek

In interpreting the principal components, it has to be emphasized that the first two components represent more than 50% of the variance of the system; the other ones are irrelevant. As the first principal component dominates the distribution of the first group and also significant for the second group, it embodies undoubtedly the effect of colloidal complexes including organic matter, iron and manganese oxides and hydroxides as well as clay particles retaining essentially the ions of heavy metals and some

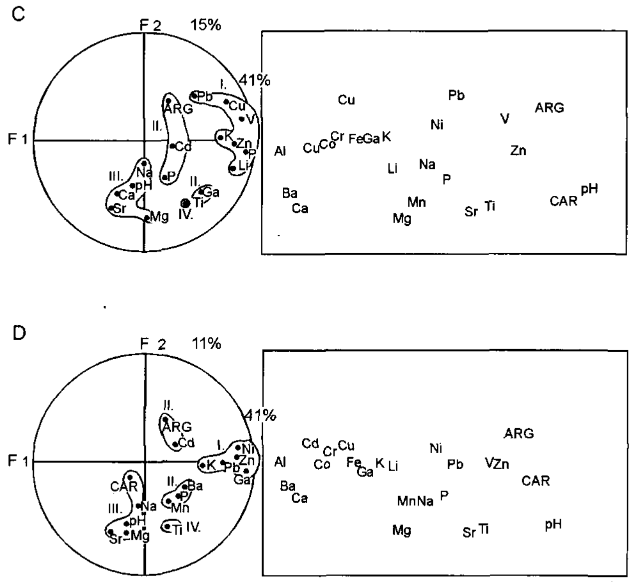

Fig. 3. "Circles of correlation"
C = First geochemical layer, D = Second geochemical layer; I, II, III, IV. Populations of elements and factors differentiated

3. ábra. Korrelációs körök
C = Első geokémiai szint, D = Második geokémiai szint; I., II., III., IV. Elkülönített elempopulációk és paraméterek

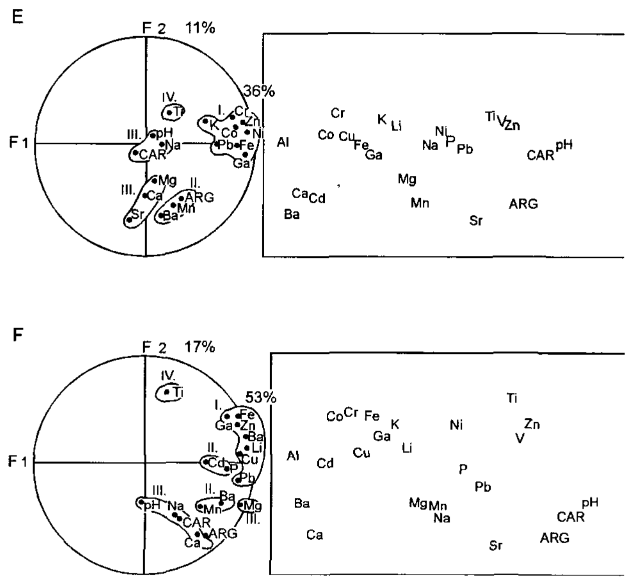

Fig. 4. "Circles of correlation"
E = Third geochemical layer, F = Fourth geochemical layer; I, II, III, IV. Populations of elements and factors differentiated

4. ábra. Korrelációs körök
E = Harmadik geokémiai szint, F = Negyedik geokémiai szint; I., II., III., IV. Elkülönített elempopulációk és paraméterek

other elements belonging to the first two groups. The major part of these elements is fixed through sorption. Under specific circumstances they can be released by ion exchange and taken up by the root system of plants. With regard to the role of colloidal complexes mentioned above, it can only be said that the humus layer binds heavy metals preferentially in soil horizon A, iron and manganese oxides and hydroxides become prominent in the zone of fluctuating ground-water, whereas clay particles are present all along the profile, becoming the exclusive representatives of those complexes below ground-water level.

The second principal component is considerably weaker, appears to determine the distribution of the third group of elements. It represents the role of some physical and chemical mechanisms like pH and redox potential acting in the soil, inhibiting the secondary precipitation of these elements leached out from the fairly reducive, humus-rich upper horizon. This fraction cannot, however be taken up by plants. The other part of these elements is fixed like the first two groups on colloidal complexes. This assertion is justified by the correlation between the first and third groups of elements (Fig. 4) below ground-water table as at this level clay particles are the only agents retaining both groups.

No clear trends are attributable to the remaining principal components due to the obliteration of other, undoubtedly complex mechanisms determining the distribution of nutrient elements in the soil, so their interpretation would rather be risky.

As far as titanium is concerned, its strange behaviour can be linked to the weathering of biotite or leucoxene. Not even nitric acid is capable of removing titanium it from rutile or anatase.

A strong positive correlation between the first principal component and heavy metals on the one hand and a negative correlation between the second component and the third group on the other hand is clearly recognizable from the regional distribution maps of principal components and concentrations of chromium, iron, lead and strontium in the first agrochemical zone (Figs. 5, 6, 7, 8, 9 and 10).

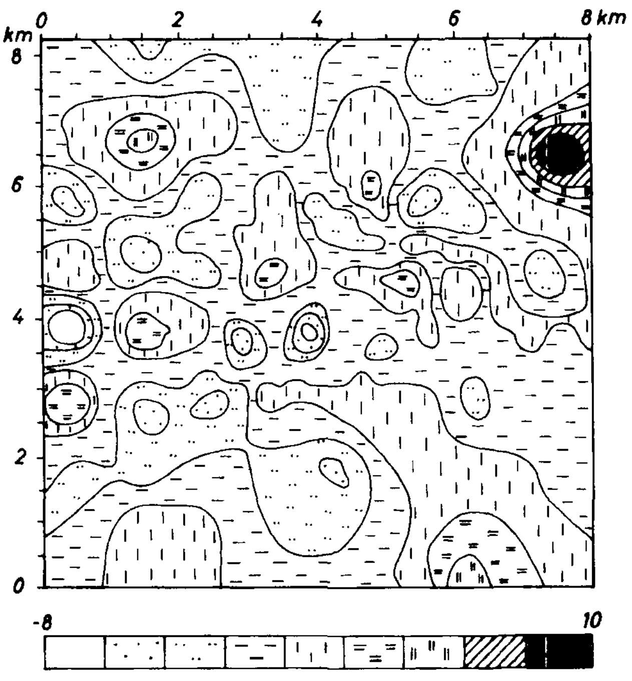

Fig. 5. The areal distribution of the 1st principal component (F1) in the uppermost geochemical layer

5. ábra. Az 1. főkomponens (F1) területi eloszlása a legfelső geokémiai szintben

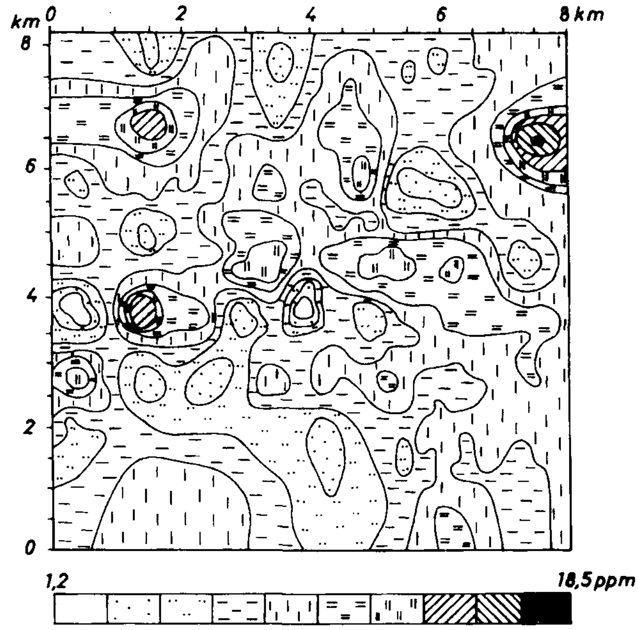

Fig. 6. The areal distribution of the concentration of the chrome in the uppermost geochemical layer

6. ábra. A krómkoncentráció területi eloszlása a legfelső geokémiai szintben

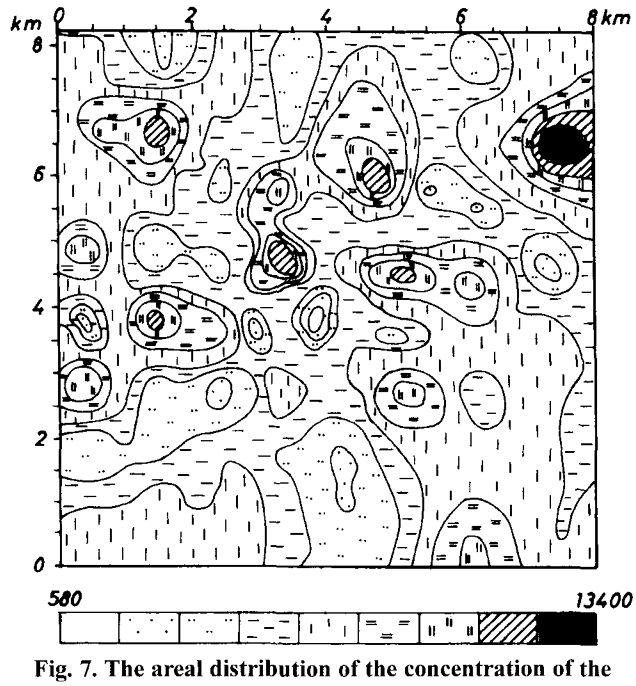

Fig. 7. The areal distribution of the concentration of the iron in the uppermost geochemical layer (ppm)

7. ábra. A vaskoncentráció területi eloszlása a legfelső geokémiai szintben (ppm)

Conclusions

With regard to many of the elements analysed within the framework of this study, there are certain ranges of concentration necessary to bring about benign effects on the growth of plants. This interval varies as a function of the given plant species as well as the physical and chemi-

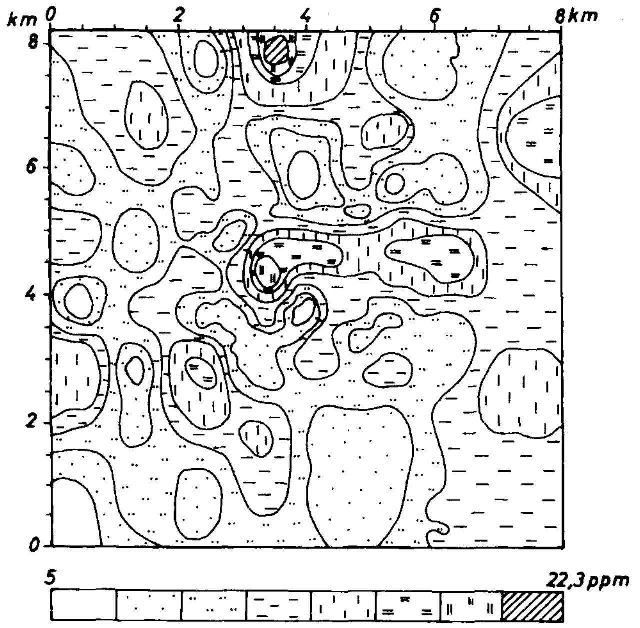

Fig. 8. The areal distribution of the concentration of the lead in the uppermost geochemical layer

8. ábra. Az ólomkoncentráció eloszlása a legfelső geokémiai szintben

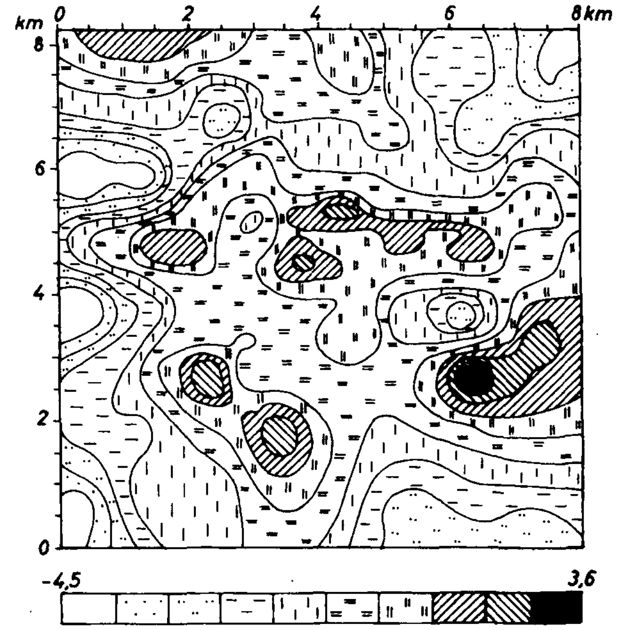

Fig. 9. The areal distribution of the 2nd principal component (F2) in the uppermost geochemical layer

9. ábra. A 2. főkomponens (F2) területi eloszlása a legfelső geokémiai szintben

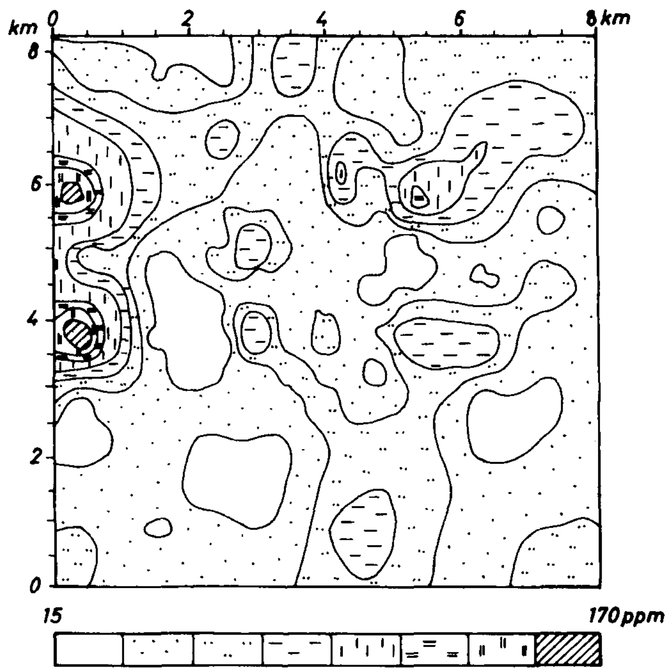

Fig. 10. The areal distribution of the concentration of the strontium in the uppermost geochemical layer

10. ábra. A stronciumkoncentráció területi eloszlása a legfelső geokémiai szintben

cal conditions prevailing in the soil. Values remaining under the lower or exceeding the upper threshold of those ranges lead to a considerable decrease in the productivity of the soil or even to poisoning effects. The BFK technique, which was applied in this study, represents a major step in identifying major factors acting for or against the availability of nutrients in sufficient amount.

Except for a slightly elevated level of cadmium probably due to migration in ground-water from the north of the pilot area, subjected to the application of fertilizers, no anomalous concentrations were identified. High pH values necessitate, however certain measures in the future to avoid asphyxiation of the soil.

In addition to providing an invaluable tool for determining the distribution and the character of correlations between nutrient elements, this multivariate method can also be successfully used in the monitoring of the migration of subsurface contamination. It cannot, however, be applied directly to mapping lithological formations.

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A TÁPELEMEK ELOSZLÁSA A SZARVASI MINTATERÜLET TALAJAIBAN

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Tárgyszavak: BFK módszer, geokémiai szintek, salétromsavas kivonatolási módszer, főkomponens analízis, komplex vegyületek, szennyezőanyag, migráció.

ETO: 631.42(439.175) 556.32:519.23(439.175) 504.064(439.175)

Az 1970-es években még a Síkvidéki Osztály kezdeményezésére indult egy projekt, melynek célja egy standard agrogeológiai kutatási módszer, a szerzők nevének kezdőbetűi alapján BFK módszer kidolgozása volt a növények számára nélkülözhetetlen tápelemek talajban való eloszlásának vizsgálatára. A módszer újszerűsége abban rejlik, hogy a hagyományosan tanulmányozott felső 2 m helyett az elemek eloszlását a talaj–anyakőzet–talajvíz rendszerben a szelvény felső 10 méterében kutatja. A vizsgált számos mintaterület közt az e munka tárgyát képező szarvasi körzet egyike a legutóbb feltártaknak.

A szarvasi kutatás által várt közvetlen eredmények a tápelemek eloszlásának törvényszerűségei mellett az egyes geokémiai szinteken egy populációt alkotó elemek halmazainak meghatározását, az elemeloszlásoknak a mélységgel való változását, illetve az ezeket a változásokat irányító fizikai-kémiai viszonyok tisztázását foglalják magukba.

Az előzetesen feltárt mintaterületeken elvégzett vizsgálatok alapján a kutatott 10 méteres zóna a következő 4 geokémiai szintre lett bontva:

1. A talaj hagyományos A szintje.
2. A nyugalmi talajvízszint és a talajvízszint ingadozásának felső határa közé eső zóna.
3. A nyugalmi talajvízszint és a talajvízszint ingadozásának alsó határa közé eső zóna.
4. Állandóan a talajvízszint alatt elhelyezkedő zóna.

A feltárás során a mintegy 64 km^2-es területen 94 db, átlagosan 10 m mély fúrás mélyült 500x500, illetve 1000x1000 méteres hálóban, fúrásonként az említett geokémiai szinteknek megfelelően 4-4 db geokémiai vizsgálatra szánt minta vételével a szemeloszlás, agyag- és karbonáttartalom, valamint a pH meghatározásával kiegészítve. A geokémiai minták elemeinek kivonatolására salétromsavat használtak, a kivont elemtartalmat pedig részben atomabszorpciós, részben pedig ICP multielemes módszerrel határozták meg. Az elemtartalmakat illetően tehát 376 minta állt rendelkezésre, mely mintegy 9000 adat feldolgozását tette lehetővé.

Az eredmények feldolgozása egy- illetve többváltozós statisztikai módszerekkel történt mind a teljes profilra, mind külön-külön, az említett négy geokémiai szintre vonatkozóan. Mindkét módszer a következő 4 elempopuláció elválasztását tette lehetővé, melyeken belül az elemek eloszlása a profilon belül többé-kevésbé homogénnek tekinthető:

I. — Al, Co, Cr, Cu, Fe, Ga, K, Li, Ni, Pb, V, Zn.
II. — Ba, Cd, Mn, P.

III. — Ca, Mg, Na, Sr.
IV. — Ti.

Az egyváltozós vizsgálati módszer szerint az egyes szintek átlagainak az összátlaghoz viszonyított alakulása alapján az első és második elemcsoport tagjai, tehát uralkodóan a nehézfémek a talaj legfelső, humuszban gazdag szintjében mutatnak relatív felhalmozódást, a második szinten mennyiségük csökken, lejjebb nem változik. Az úgynevezett karbonátos elemek ezzel szemben a 2. és 3. szintben, tehát a talajvíz ingadozási zónájában koncentrálódnak, a humuszos, illetve a talajvíz alatti zóna kedvezőtlen számukra. A titán mennyisége ezzel szemben a mélységgel lefelé fokozatosan nő (1. ábra).

Az elemek egyváltozós módszerrel való fenti 4 csoportba sorolhatóságának igazolására, valamint az eloszlásukat meghatározó fizikai–kémiai mechanizmusok kimutatására az elemek koncentrációjára vonatkozó adatokat *főkomponens analízisnek* vetettük alá. A főkomponens analízis többváltozós statisztikai módszer, mely a változók populációjának egyedei közötti korrelációra építve az eredeti (N számú) változót új, az eredetinél — legalábbis jelentőségét tekintve — kisebb számú változóvá (n) transzformálja. Ezeket a transzformált változókat *főkomponens*eknek nevezzük, s 1–n-ig terjedő sorszámmal jelöljük. Az eredeti változókat (N) leíró N dimenziós térben az első főkomponens geometriailag azt az irányt képviseli, melyben a populáció szórása a legnagyobb. A második főkomponens erre ortogonálisan jelöli ki a második legnagyobb szórású irányt stb. Általánosságban véve igaz, hogy főkomponens analízist csak egymással bizonyos mértékig korreláló változók esetén célszerű alkalmazni, s gyakorlati jelentőség csupán az első 2–4 főkomponensnek tulajdonítható, a továbbiak háttéreffektust képviselnek. Az említett első 2–4 főkomponens az N dimenziós térben a változókat az egymás közti korrelációt kihasználva populáció csoportokba tömöríti, melyek elhelyezkedését jelen esetben, tehát az elemek eloszlását illetően, a főkomponens által képviselt és általuk értelmezni próbált fizikai–kémiai folyamatok és jelenségek határozzák meg. A főkomponens analízissel kapcsolatos tudnivalókat számos forrásmunka tárgyalja, ezért itt erre nem térünk ki részletesen.

A 2. ábrán látható, hogy a főkomponens analízis eredményeit 2 dimenziós térben szemléltető korrelációs körök megerősítik az egyváltozós módszerrel már sejtett négyfajta elempopuláció létezését mind az F1–F2, mind pedig az F2–F3 faktor–főkomponens viszonyában. A legszorosabb korrelációt a nehézfémek (I. csoport) mutatják (2–4. ábra).

Az eredmények interpretációja szerint az F1 főkomponens, mely az I. és II. elemcsoport eloszlásának alapvető meghatározója, azoknak a komplex vegyületeknek a hatását képviseli (tehát a szervesanyagét, agyagásványokét, valamint a vas és mangán oxidjaiét és hidroxidjaiét), melyeknek felületén a nehézfémek és az e csoportokba sorolt további elemek megkötődnek, s melyekről a fizikai–kémiai viszonyok függvényében ioncsere útján mobilizálhatók.

A karbonátos elemek csoportját illetően, a salétromsavas kivonatolási módszer két különböző frakciójukat mobilizálja. Az egyik a talajréteg humuszban gazdag környezetéből kioldott, s a talajvíz felső ingadozási szintjének (2. geokémiai szint) kevésbé oxigénszegény zónájában másodlagosan kicsapódott alkotó, melynek a 2. és a 3. nívóban tapasztalható dúsulás köszönhető, a másik pedig szintén az előbb említett vegyületkomplexumokon megkötött összetevő, mely a talajvízszint alatt egyeduralkodóvá válik, s ennek köszönhetően jelentősen megnő az I–II. és III. elemcsoport közötti korreláció. Az F2 főkomponens, úgy tűnik, a profilban uralkodó fizikai–kémiai viszonyok függvényében interpretálható.

A titán titokzatos viselkedése talán a biotit, illetve leukoxén mállására vezethető vissza, hisz a salétromsav nem oldhatja ki őt sem a rutilból, sem pedig az anatázból.

Következésképpen megállapítható, hogy az F1, tehát a komplex vegyületek adszorbciós hatását leíró főkomponens területi eloszlása gyakorlatilag megegyezik az I. csoport tagjaiéval, példaképpen a króméval és a vaséval, míg az F2 főkomponens eloszlása a stronciuménak ellenkezője (5–10. ábra).

E kutatási módszer jelentősége a következőképpen foglalható össze. A vizsgált elemek nagy részének bizonyítottan létezik egy minimális, illetve maximális mennyiségi korlátja. Az előbbi a növények számára feltétlen szükséges, utóbbi pedig a már számukra mérgező hatásokat kiváltó túlzott mennyiséget képviseli. A mintaterületek kutatásának BFK módszere, s a bemutatott geomatematikai eljárás azokat a földtani és fizikai–kémiai viszonyokat tárja fel, melyek az egyes elemeknek a különböző növényfajtákra vonatkozó határértéken belüli, illetve azt átlépő eloszlásainak törvényszerűségeit határozzák meg, s így fontos információt nyújtanak a mezőgazdaság számára. A módszer hatékonyan alkalmazható a talajszennyezett anyagok migrációjának nyomon követésére is.

ANN. REP. OF THE GEOLOGICAL INSTITUTE OF HUNGARY, 1992–1993/II: 111–115 (1999)

TRIASSIC SOURCED OIL SHOWS NEAR BUDAPEST

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Manuscript received in 1994.

Keywords: hydrocarbons, parent rock, correlation, maturity, heat flow, migration, volcanic effect, Miocene, Budapest, oil show, Upper Triassic, biodegradation

UDC: 553.982(439 Budapest) 551.761:552.578(439 Budapest)

The study of the oil shows, proving oil generation and migration in the pre-Neogene strata of Hungary is an important task of the Geological Institute of Hungary. Gas chromatograms of the bacterially degraded oil shows present in the Upper Triassic limestone and in the Middle Miocene dacite in the vicinity of Budapest suggest that the marls and cherty, bituminous limestones of the Upper Triassic Mátyáshegy Formation, relatively rich in algal organic matter sourced the oil. Generation and migration likely were contemoraneous with the Middle Miocene volcanic activity and the resulting increase of heat flux.

Introduction

Geological and geochemical data and considerations suggest that the pre-Neogene sediments of Hungary will be a focus of interest in oil exploration in the near future. Oil shows as evidence of migration are of obvious importance for play assessment. A study of pre-Neogene related oil shows is in progress in the Geological Institute of Hungary. Here we report oil shows found near Budapest and attempt to correlate them with a known Upper Triassic source rock.

Geological setting of the shows and the possible source rocks

The Pilismarót–3 (hereafter Pm–3) water well (for location see Figs. 1 and 3) has reached fractured, karstified Upper Triassic limestone at a depth of 437.2 m beneath Oligocene sedimentary rocks. Abundant bitumen staining (451.9–469.2 m) and the presence of oil (484.2 m) was reported from fractures and vugs of the core material by F. SZÉKY (1959). In the Oligocene section of the Pilisszentlászló–2 (hereafter Pszl–2) well several mid-Miocene dacitic intrusive bodies were intersected. In one of them the fracture-filling pink clay (depth interval 553.0–554.7 m) has shown strong pale-yellow fluorescence suggesting the presence of oil hydrocarbons. Soxhlet extraction of the clay yielded a significant quantity of oil-like EOM.

Based on the small oil fields in N-Hungary reservoired in the sandstone lenses of the Lower Oligocene Kiscell Clay Formation, T. SZALAI (1959) suggested this formation as the source of the Pm–3 oil show. We note that then the theory of oil generation accepted today and the poor source quality of the Kiscell Clay, were both unknown.

In terms of organic richness and kerogen type the Carnian (Upper Triassic) Mátyáshegy Formation and the Lower Oligocene Tard Clay Formation can be considered as oil source rock present in the study area.

The Mátyáshegy Fm consists of bituminous limestone and dolomite with flints and numerous thick marly banks interfingering with the Carnian Veszprém Marl Formation (CSÁSZÁR, HAAS 1983). It is covered by the Carnian-Norian Hauptdolomite Formation and is mapped together with it (Fig. 1). So it is considered as present in the bulk of the study area. Its outcrop is known in the Mátyás-hegy Hill (Budapest, Fig. 1). Its source rock characteristics were studied in the Zsámbék–14 (Zs–14) core-section by BRUKNER and VETŐ (1983). According to their results the depth interval 590–700 m contains fair to good oil source rocks.

The Tard Clay Fm is present in the SE part of the study area (Fig. 1). Its source rock characteristics were studied in details in the Alcsútdoboz–3 (Ad–3) core hole section by BRUKNER-WEIN et al. (1990). Their results show the presence of fair to good oil source rocks in the depth interval 635–680 m.

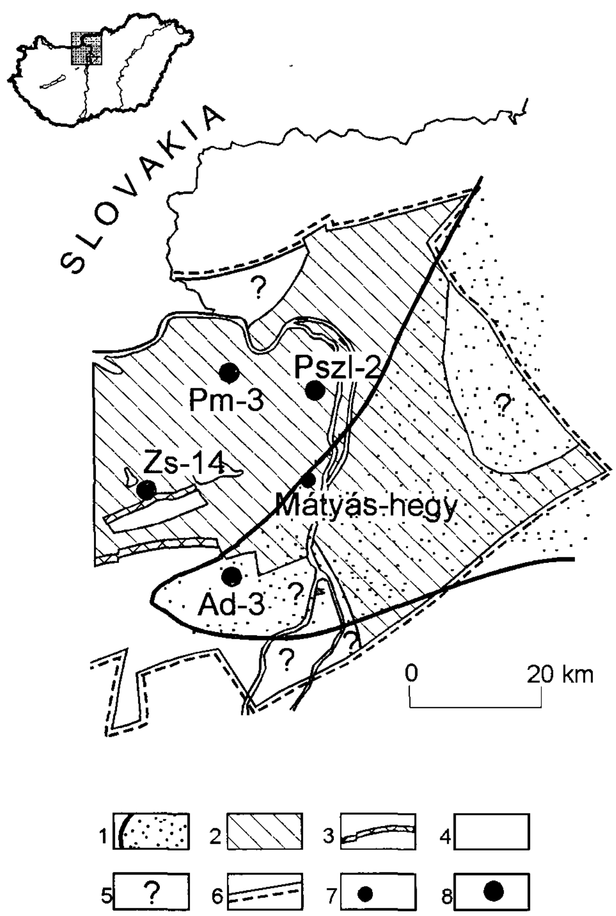

Fig. 1. Cenozoic subcrop map of the eastern end of the Transdanubian Central Range with the subsurface extent of the Oligocene Tard Clay Fm (1)

1. After NAGYMAROSY (1990), 2–5. After FÜLÖP et al. (1987) and KORPÁS, CSILLAGNÉ (1982): 2. Hauptdolomit Fm to lowermost Cretaceous, 3. Veszprém Marl Fm, 4. Permian to Ladinian, 5. Upper Paleozoic–Mesozoic in general, 6. Boundary of the TCR, 7. Outcrop mentioned, 8. Oil show

1. ábra. A Dunántúli-középhegység K-i elvégződésének földtani térképe a kainozoikum elhagyásával, a Tardi Agyag elterjedésének (1) feltüntetésével

1. NAGYMAROSY 1990 után, 2–5. FÜLÖP et al. [1987] és KORPÁS, CSILLAGNÉ [1982] után: 2. A Fődolomittól a legalsó kréta képződményekig, 3. Veszprémi Márga Formáció, 4. Permi–ladin képződmények, 5. Felső-paleozoikum–mezozoikum általában, 6. A Dunántúli-középhegység határa, 7. Kibúvás, 8. Olajnyom

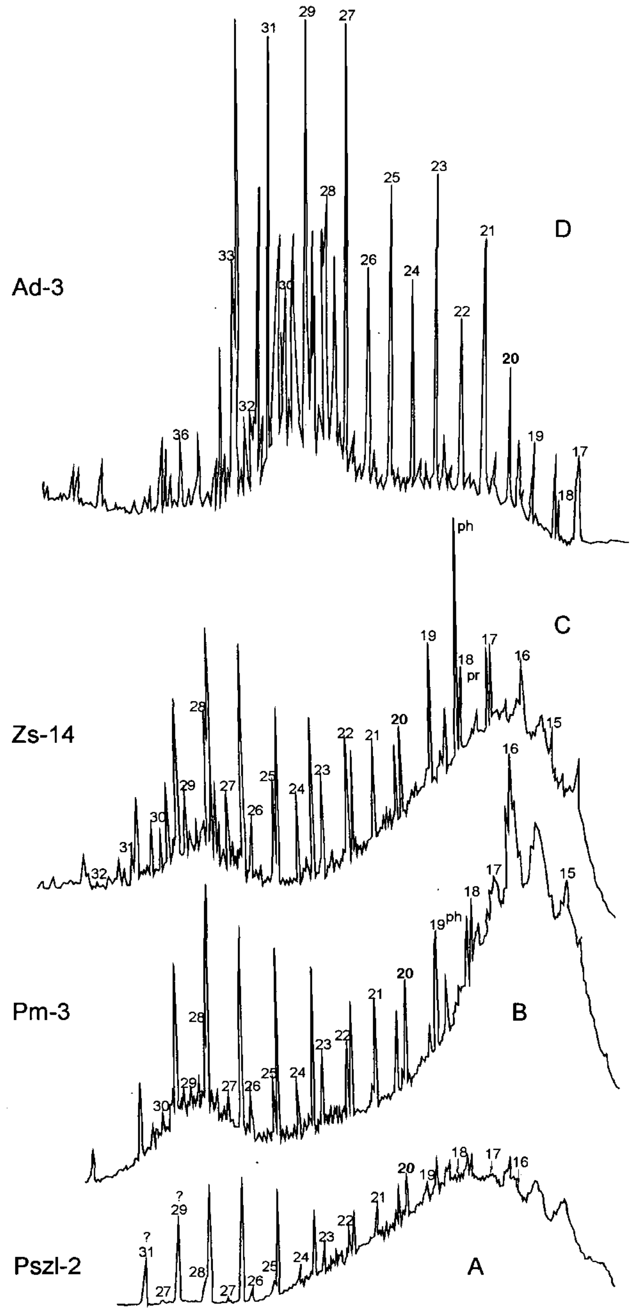

Fig. 2. Gas chromatograms of the saturate fraction of the oil shows and the Zs-14 and Ad-3 extracts

20. C_{20} n-alkane, pr. Pristane, ph. Phytane; the Ad-3 GC-curve after BRUKNER-WEIN et al. (1990)

2. ábra. Az olajnyomok valamint a Zs-14 és az Ad-3 extraktumok telített CH-frakcióinak gázkromatogramjai

20. C_{20} n-alkán, pr. Prisztán, ph. Fitán. Az Ad-3 görbe BRUKNER-WEIN et al. (1990) szerint

Comparison of the oil shows and the source rock extracts

In absence of GC-MS data the only possible approach to correlate the shows with source candidates is the fingerprint method. Gas chromatograms of the saturated fractions of the two oil shows reported above are shown on Fig. 2. The A and B curves reveal striking similarities (1) and some differences (2). (1) Based on their position relative to the neighbouring n-alkanes, the unidentified molecules (likely to be cycloalkanes) present in significant concentration are the same in the two oil shows; the n-C_{28} is much more abundant than the n-C_{27}. (2) The ratio of a cycloalkane (?) to the neighbouring n-alkane expressed in the ratio of the corresponding peak highs is much higher in the Pszl–2 than in the Pm–3 and the "hump" in the C_{25}–C_{30} interval is present in the Pm–3 but it is absent in the Pszl–2.

The C gas chromatogram shown on Fig. 2 represents the saturated HC fraction of the extract obtained from a Zs–14 Mátyáshegy Fm sample. The cycloalkanes (?) present in significant concentration are likely to be the same as in the oil shows but the cycloalkane (?) to n-alkane ratios are much lower in the extract than in the oil shows.

The D gas chromatogram shown on Fig. 2 represents the saturated HC fraction of a typical Tard Clay extract. While in the Tard Clay extract the n-alkane distribution is characterised by a strong predominance of the odd carbon number molecules, as is expected in immature clastic sediments, in the oil shows (and the Zs–14 extract) the neighbouring even carbon number and odd carbon number n-alkanes are in roughly equal concentrations. So the Tard Clay can be discarded as the source of the shows.

The striking similarities reported above make it very likely that the Pm–3 and Pszl–2 oil shows have a common source and this source is the Mátyáshegy Formation. The lack of the "hump" in the C_{25}–C_{30} range in the Pszl–2 oil show suggests some regional variability of source rock characteristics.

When we move from the Zs–14 to Pszl–2 via Pm–3, the abundance of the cycloalkanes (?) relative to the neighbouring n-alkanes increases. This phenomenon can be explained by bacterial degradation of the oil increasing in this direction: the Zs–14 Mátyáshegy Fm extract is obviously free of bacterial effect, the Pm–3 oil suffered only a moderate degradation, while the oil in intimate contact with the clay particles in the fracture filling of the Pszl–2 dacite is deeply degraded.

Maturity considerations and the timing of generation and migration

To see the real significance of the supposed correlation between the shows and the Mátyáshegy Formation we have to consider the maturity pattern of the Triassic strata and the timing of generation and migration. Horváth et al. (1981) stated that the top of the oil window lies inside the Triassic in the Transdanubian Central Range. This picture was refined by I. Vető (1988) who suggested an asymmetric maturity pattern for the Triassic strata of the Transdanubian Central Range, e.g. they show a lower maturity on the SE flank of the mountain than on its NW flank. Vető did not discuss if this asymmetry was created during the burial cycle terminated in the mid-Cretaceous or whether a later event also had some responsibility for it.

Looking at our study area we see that the Triassic strata penetrated by the Zs–14 well contain immature kerogen as shown by the Hauptdolomite R_0 data (0.39–0.42% in the depth interval 300–500 m, Laczó 1984). The Mátyáshegy Fm lying about 200 m deeper has to be of practically the same maturity. We note that the Zs–14 well was drilled on the SE flank of the mountain. On the other hand the Eocene–Oligocene coals mined in the study area, show local average R_0 values ranging between 0.43% and 0.51% (Laczó 1982). In the western part of the study area the Palaeogene coal measures and the Mátyáshegy Fm are separated by a sequence more than 1 km thick, ranging from the Upper Triassic Hauptdolomite Fm to the Lower Cretaceous. This means that the maturity of the Mátyáshegy Fm on the NW flank of the mountain has to be significantly higher than that in the Zs–14 core-section.

In view of the present-day depth and the past burial of the coal measures their maturity is surprisingly high and some post-Oligocene thermal event is needed to explain it. All of these facts support that the maturity asymmetry mentioned above is —at least in our study area— a post-Oligocene feature.

These considerations led us to assume that oil generation in the Mátyáshegy Fm occurred in the post-Oligocene. Since the oil show of the Pszl–2 is reservoired in a mid-Miocene dacite body the time interval for oil generation (and migration) is relatively well constrained and the supposed thermal event seems to be related to the mid-Miocene igneous activity resulting in the strato-volcanic sequence which covers a large area NW of Budapest (Fig. 3). We should note the coincidence in area of the oil shows and the outcrops of the Miocene strato-volcanic sequence (Fig. 3), but we do not think that the thermal effect was produced by the strato-volcanic sequence itself, since the downward heat flux due to its cooling should have been insignificant. It is more likely that the thermal effect was produced by an igneous activity related regional increase of heat flux. So the eastern end of the Transdanubian Central Range, which is characterised by presence of

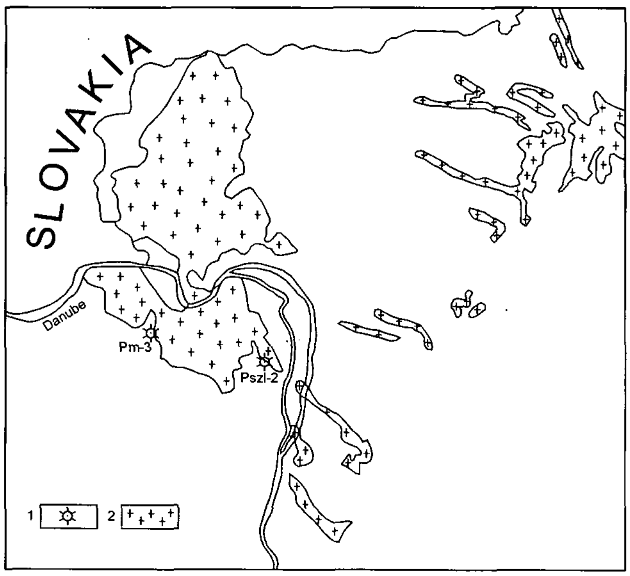

Fig. 3. Distribution of mid-Miocene volcanic rocks after Rónai et al. (1984)
1. Boreholes mentioned

3. ábra. A középső-miocén vulkanitok elterjedése a felszínen és a kvarter alatt. Rónai et al. (1984) után
1. Említett fúrások

Upper Triassic source rocks and is affected by mid-Miocene igneous activity —the Szentendre–Visegrád, Börzsöny and Cserhát area (see Fig. 3)— is promising for oil generation and migration. The distance of about 15 km separating the two oil shows is also evidence for the considerable area of the migration. It is worth noting that in the eastern part of the study area the Lower Oligocene Tard Clay Fm could also have been affected by the thermal event related to the mid-Miocene volcanism, so here oil generated by this source rock could also have contributed to oil accumulations.

The discussion of the possible traps and the reserves to be expected are beyond the scope of this paper.

Conclusions

The most probable source of the Pm–3 and Pszl–2 oil shows are the organic-rich carbonates and marls of the Upper Triassic Mátyáshegy Formation. The oil generation occurred in the post-Oligocene and is likely to have been caused by an increase of heat flux related to the mid-Miocene igneous activity.

Acknowledgements

The advices and criticism of LÁSZLÓ KORPÁS are much appreciated. The English text benefited from the revision of LÁSZLÓ ÓDOR and ALICE BRUKNER-WEIN.

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TRIÁSZ ANYAKŐZETBŐL SZÁRMAZÓ OLAJNYOMOK BUDAPEST KÖRNYÉKÉN

VETŐ ISTVÁN

Magyar Állami Földtani Intézet, 1143 Budapest, Stefánia út 14.

Tárgyszavak: szénhidrogén, anyakőzet, korreláció, érettség, hőáramlás, migráció, vulkáni hatás, triász, miocén, Budapest, olajnyom, felső-triász, biodegradáció

ETO: 551.761:552.578. (439 Budapest) 553.982(439Budapest)

A hazai olajkutatás várhatóan egyre inkább az idősebb medencék felé fordul. A preneogén üledékekben történt generációt és migrációt bizonyító olajnyomok kutatása ezért fontos feladata a MÁFI-nak. A Pilismarót Pm–3 fúrás felső-triász mészkövében ill. a Pilisszentlászló Pszl–2 fúrás középső-miocén dácitjában megismert, bakteriálisan degradált olajnyomok és a területen anyakőzetként számbajöhető üledékek — a felső-triász Mátyáshegyi F. és az alsó-oligocén Tardi Agyag F. — szerves extraktumának gázkromatográfiás vizsgálata szerint az olajnyomok legvalószínűbb anyakőzete a Mátyáshegyi Formáció. E formáció tűzköves, bitumenes karbonátjai és a közéjük települő márgapadok a korábbi szervesgeokémiai vizsgálat szerint jó–közepes minőségű olaj anyakőzetnek bizonyultak.

A Budapest környéki paleogén szenek mai és multbeli mélységüket tekintve meglepően magas érettségét csak egy, az oligocénnél fiatalabb termális esemény, nagy valószínűséggel a középső-miocén hőáramnak az egykorú magmás tevékenységhez kapcsolódó megnövekedése magyarázhatja. A pilisszentlászlói dácit középső-miocén kora ennek jól megfelel. Valószínűnek tartjuk, hogy a Dunántúli Középhegység ÉK-i elvégződésében a felső-triász anyakőzetekben olajgeneráció és migráció ment végbe a középsőmiocén folyamán.

GEOLOGICAL CONDITIONS AROUND THE CONE OF DEPRESSION ARISING FROM PUMPING OF MINE WATERS IN THE NYIRÁD REGION, WESTERN HUNGARY

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Manuscript received in 1994.

Keywords: karst hydrology, karst-water table, Upper Triassic, Upper Cretaceous, carbonate rocks, aquifers, impervious rocks, horizontal movements, Bakony Mountains, cone of depression, syncline, Hungary

UDC: 556.332.46(234.373.1) 552.54.+551.763.3(234.373.1) 552.54+551.761.3(234.373.1) 556.33(234.373.1)

The first step in the rehabilitation of the karst water system in the Transdanubian Central Range is the refilling of the depression cone which formed through lowering the water level because of bauxite mining in Nyirád. Analysis of the geological processes may contribute to the recognition of different geological factors influencing water flow.

New knowledge concerning the Nyirád region enables us to understand the hydrogeological processes in this area, and to refine the hydrogeological model of the whole of the Transdanubian Central Range.

Introduction

The karst water reserve in the Transdanubian Central Range (TCR; Fig. 1) is an integral part of the drinking water supply of Hungary. Therefore it is very important to know its condition. It is a well known fact that the level of karst water table in the area has significantly decreased as a consequence of pumping during mining and has given rise a critical situation. In recent years the amount of water pumped has been considerably reduced and the rehabilitation of the region has started. The refilling of the cones of depression did not proceed as expected. This directed the attention to the fact that there was a need for further analysis of the factors influencing the level and flow of karst water. Investigation of the filling processes supplies a unique opportunity to accomplish this work.

The investigation started in 1991 in the Geological Institute of Hungary with study of the filling processes in the Nyirád depression area. Our purpose was to get a thorough knowledge of the geological factors influencing the karst water table from an area covered by a dense observational network. Water level data were supplied by Dr. S. Farkas, hydrogeologist at the Bakony Bauxite Mines. Study of the depression in the Dorog region started in 1992 and the whole area affected by the drop water level will be investigated. Experience gathered from different regions can be used for refining the hydrogeological model in the less known areas of the TCR and for forecasting the karst water level. Detailed analysis of the Nyirád region was made possible by the fact that we had

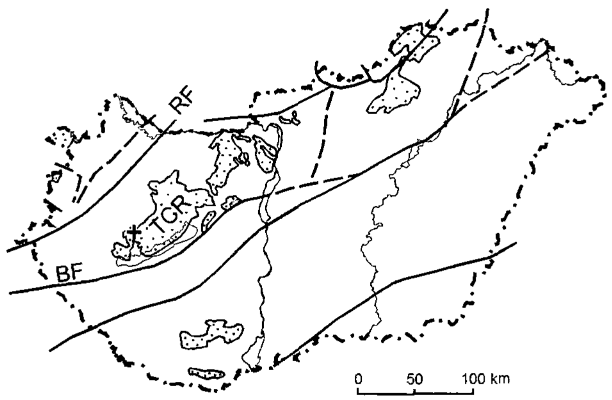

Fig. 1. Structural position of the Transdanubian Central Range (TCR)

RF = Rába fault, BF = Balaton fault, + The middle of the area investigated

1. ábra. A Dunántúli-középhegységi (TCR) zóna nagyszerkezeti helyzete

RF = Rába vonal, BF = Balaton vonal, + a vizsgált terület centruma

thorough and up to date geological information on this area and on its surroundings. The Bakony, Balaton and Keszthely areas were recently surveyed and reported. A definitive monograph was published about the Sümeg area (HAAS et al. 1984, 1985). Significant information was obtained also in other areas by exploration geophysics and drilling.

Main geological factors determining the structure and extent of the Mesozoic basement

The boundaries of the structural unit of the Transdanubian Central Range are formed by two notable tectonic lines: the Rába river on NW and the line of the Balaton on S. The zone of the TCR had been moved about 150–200 km to the east along these horizontal lines from its original position during the Cenozoic, mainly at the end of the Oligocene and in the Miocene.

The existence of this reverse fault is important from our point of view because the formation of a lot of structural elements which play a vital role in the subsurface water flow can be related to these movements. Structural features of the TCR were basically determined by two events. One of them is the Austrian–Pre-Gosau tectonic phase which caused the first folding of the Alps during the Middle Cretaceous and before the Late Cretaceous. During this process a synclinorium structure was formed in the formations deposited in the zone of the TCR still in its original place (Fig. 2). It is probable that Middle

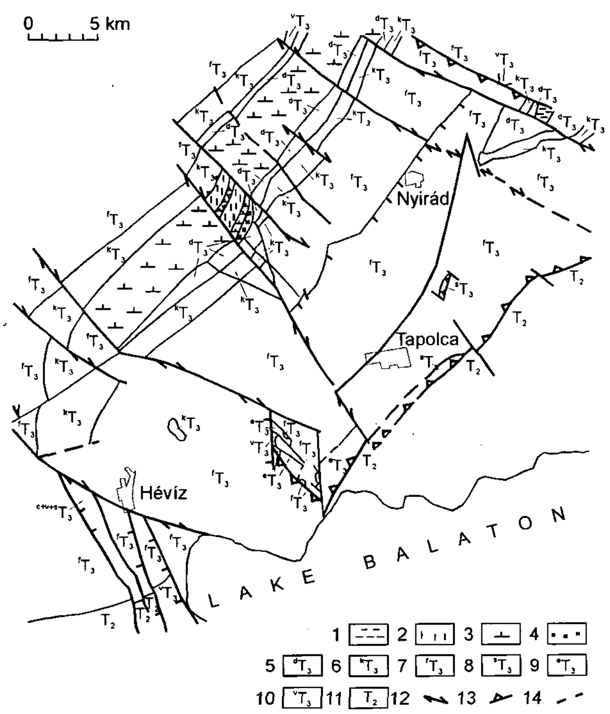

Fig. 2. Upper Cretaceous subcrop map, Nyirád area
1. Middle Cretaceous (Albian) formations, 2. Middle Cretaceous (Aptian) Tata Limestone Fm, 3. Lower Cretaceous formations, 4. Jurassic formations, 5. Kardosrét Limestone and Dachstein Limestone Fms, 6. Kössen Marl Fm, 7. Hauptdolomit Fm, 8. Sándorhegy Limestone Fm, 9. Ederics Fm (limestone and dolomite, 10. Veszprém Marl Fm, 11. Middle Triassic formations, 12. Horizontal displacement, 13. Reverse fault, 14. Other structural elements

2. ábra. A felső-kréta képződmények alatti felszín kifejlődése Nyirád környékén
1. Középső-kréta (albai) képződmények, 2. Középső-kréta (apti) Tatai Mészkő Formáció, 3. Alsó-kréta képződmények, 4. Jura képződmények, 5. Kardosréti Mészkő F. és Dachsteini Mészkő F., 6. Kösseni Márga F., 7. Fődolomit F., 8. Sándorhegyi Mészkő F., 9. Edericsi F. (mészkő és dolomit), 10. Veszprémi Márga F., 11. Középső-triász képződmények, 12. Horizontális elmozdulás, 13. Feltolódás, 14. Egyéb szerkezeti elem

Cretaceous formations were on the surface in the middle strip of the zone with NE–SW strike direction containing immature aleurite, clay and marl layers and thick carbonate beds in some places. Deeper laying older rocks appear on the surface gradually northwards and southwards in correspondence with the syncline structure. Upper Triassic carbonate rocks, first of all the Hauptdolomit, in a thickness over 1000 m, formed the surface in a very extended area, due to erosion.

In some areas folded and thrusted structures were formed during the tectonic phase. A well known area of this type is in the Sümeg region (Sümeg–Mogyorós-domb). It is several km wide and it is steeply and strongly uplifted, folded between the NNW–SSE oriented tectonic lines which caused a slight horizontal displacement.

Also a consequence of the strong tectonic activity is that the middle strip of the syncline is considerably eroded and that due to denudation older rocks are appear in the strip of the Middle Cretaceous formations. Apart from analogies and historical considerations, the time of the shaping and erosion of the syncline structure and the formation of the folded and thrusted structure is revealed by the fact that this effect can not be observed in the Upper Cretaceous formations in these areas.

The development of NE–SW directed reverse fault lines can also be connected to this tectonic phase. Among these are the Litér line and other structural lines and zones causing parallel thrusts which separate the Bakony from the Balaton Highlands and separate the two regions to distinct hydrogeological units.

The second significant event in the evolution of the area is the shifting in E–NE direction. During the tectonic movement that began at the end of the Oligocene and reached its maximum intensity in the Miocene the syncline structure was conserved in the NE–SW oriented zone. Naturally, the whole area did not behave as a uniform rigid block, but subregions —moving often independently and echelon-like— were formed along the lines of the reverse fault, often through the reactivation of earlier tectonic lines (Fig. 2). The tectonic lines causing right or left lateral tear faults can be properly tracked by investigating the facies relations in the Upper Cretaceous and in the Eocene. The irregularities in the spread and the relations between the different facies point to Miocene movements since the deposition of the rocks took place after the Austrian–Pre-Gosauan movements. The horizontal displacement lines have three hydrogeological meanings. They played a substantial role in the formation of the hydrogeologically important Miocene basins having significant sediment thickness; which, according to recent investigations, can be related to these lines (DUDKO et al. 1992), and which also had a pre-forming role in the Pannonian basalt volcanism. Interrupting the original tendencies they might have arranged different geological and hydrogeological rock units beside each other. In the rocks intersected by them, they were able to determine subsurface water flow; shown as follows:

Relation between the karst water table and the geological make-up in the area of the Nyirád depression cone

Contours of the main karst water table and the pressure surface is shown in Fig. 3 in the area of the depression cone in Nyirád in two points in time: 30th June, 1990, at the time of maximum depression and one year later 30th June, 1991. On the map showing a broader area several subregions can be distinguished on the basis of the karst water table. In the area of Ajka in NE the pressure level of the main karst water table is +15 to +20 m above sea level. At a distance of about 1 km, in the area of Padragkút these values are –40 to –70 m.

There is a NW–SE oriented Miocene reverse fault line between the two regions, along which older rocks were displaced over the Eocene layers (Fig. 2). At a distance of about 1 km in SW direction, in the Halimba area the minimum water level measured was +10 m at the end of June 1990. One year later it was –10 m. This subarea ends sharply at the "Padragkút" tectonic line which also caused a dextral tear fault 2–3 km long in a NW–SE direction. Its SW boundary is the Pusztamiske horizontal displacement line which runs almost due SW and can be related to the formation of the Pusztamiske depression which was filled by young sediments. The area of the cone of depression of Nyirád is situated in a SW of this structural line. The karst water relief in the SE Nyirád area is determined markedly by the tectonic lines running from the Nyirád–Szőc area in SW direction making an angle of about 20 degrees with each other. These tectonic lines, especially the southern one, played a very important role during the Sarmatian and Pannonian. They caused the formation of the Badenian and Sarmatian basins in the Miocene with considerable sediment thickness.

Recent structural analysis interprets the southern line as a horizontal displacement line (DUDKO et al. 1992). Basalt occurrences in Haláp and Agártető are also related to the southern part of this line as well as the thick Pannonian sediments southward. The changes in the karst water table point to good water conductivity in the direction of the strike the tectonic line and to less good one perpendicular to it (Fig. 3). The shape of the cone of depression is also markedly determined by the geological structure on the NNW side. The density of contours does not reach the values measured in the SSE but the changes in water level —in connection with the syncline structure— point to good water conductivity in the direction of strike and to a limited one perpendicular to it.

The contours are more dense where the Kössen Marl appears above the Hauptdolomit. This formation subcrops the Senonian in a 1 km wide strip between outcrops of the Hauptdolomit and Dachstein Limestone in accordance with the dip and thickness conditions. The surface gets gradually deeper parallel to this (Fig. 2).

The western boundary of the cone of depression is also determined by tectonic conditions. As at the SW and NE boundaries, also within the Nyirád block in the strict sense the depression cone is defined by the +100 m contour of the water table.

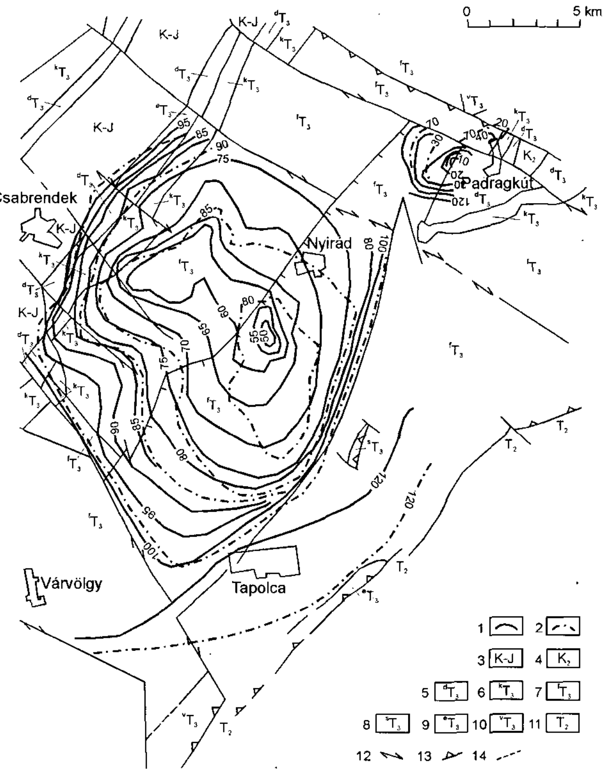

Fig. 3. Pressure contours of the main karst water table
1. Conditions on 30th June, 1990, 2. Conditions on 30th June, 1991, 3. Upper and Lower Cretaceous, Aptian and Jurassic formations, 4. Albian formations, 5–14. For legend see Fig. 2

3. ábra. A főkarsztvízszint nyomásszintje
1. 1990. június 30-i állapot, 2. 1991. június 30-i állapot, 3. Felső- és alsókréta, apti és jura képződmények, 4. Albai formációk, 5–14. Lásd a 2. ábránál

The tectonic boundary line on the west side runs to the north of Sümeg. There is another tectonic line which separates the Nagygörbő and Várvölgy basins (the Uzsa graben) to the west in the northern area and the subsidence in the Tapolca basin on the eastern side of the southern area. This pre-existing tectonic line was only reactivated in the Miocene since it probably first developed in the Austrian–Pre-Gosauan period. It constitutes the western boundary of the imbricate and thrusted 2 km long strip in Sümeg. The Mid-Cretaceous tectonic line, running at the eastern side of the steep strip along which the regular syncline structure contacts the reverse fault, can be seen only in the northern part of the region, it disappears in the southern region. Its effect is shown by the north trending embayment of the western side of the depression cone in Nyirád.

To the north there are further structures which are known to influence the level of karst water table but they are shorter and less important. The effect of geological factors which are of significance to the main karst water table in the Nyirád depression cone could be observed in the karst water table one year after the depression maximum and the start of its filling. In a later period the differences were slight and the effects insignificant.

The filling of the depression cone began with a rapid rise in the water level at the centre of the depression.

Outside the area of the depression cone, taken in a strict sense, there was a slight decrease in the water level (0.5–1 m) which continued in the next year.

The level of the karst water table inside the Upper Cretaceous limestone correlates strongly with the geological make-up.

The oldest carbonate formation which is on top of the Upper Triassic rocks suitable for karst development is the Upper Cretaceous Ugod Limestone. It lies directly on the Hauptdolomit, in a strip some hundreds of meters long, to the east of the Gerinc quarry in Sümeg. As a consequence of the overlapping deposition of the Upper Cretaceous formations the impermeable rocks of the Ajka Coal and Jákó Marl Formations (Fig. 4) were formed below the Ugod Limestone, increasing in thickness towards the NNE from the aforementioned strip. (KNAUER, GELLAI 1978.) Where the Ugod Limestone is directly deposited on the Upper Triassic Hauptdolomit, the level of the karst water table inside the limestone is the same as that of the main karst water. The same applies where the thickness of the Upper Cretaceous impermeable rocks between them is negligible.

Conclusions

1. There is a relation between the change in karst water table and the geological make-up and structure of the Transdanubian Central Range.

2. There were two specific events in the geological history of the major structural zone of the TCR with hydrogeological consequences. The first was the shaping of the syncline structure in connection with the Austrian–Pre-Gosauan tectonic phase before the Late Cretaceous. The second was its displacement by about 200 km to the east during the Miocene, along inducing several horizontal slip faults.

3. The karst water table in the region of the Nyirád depression cone and in its surroundings reflect the hydrogeological effect of the events very accurately.

4. The horizontal slip faults in this region allow very good water conductivity in the direction of the strike and less good flow perpendicular to them. Several horizontal slip fault lines can be presumed to exist between the Héviz Lake and the Nyirád depression cone, on the edges of the Uzsa graben and the Keszthely Mts.

This point merits special consideration in the analysis of the, still debated, connection between the two regions.

5. There is a narrow strip where the Upper Cretaceous Ugod Limestone is directly deposited on carbonate rocks, mainly on the Hauptdolomit, which are the main karst water reservoirs. The hydrogeological effect of this fact is eminently demonstrated.

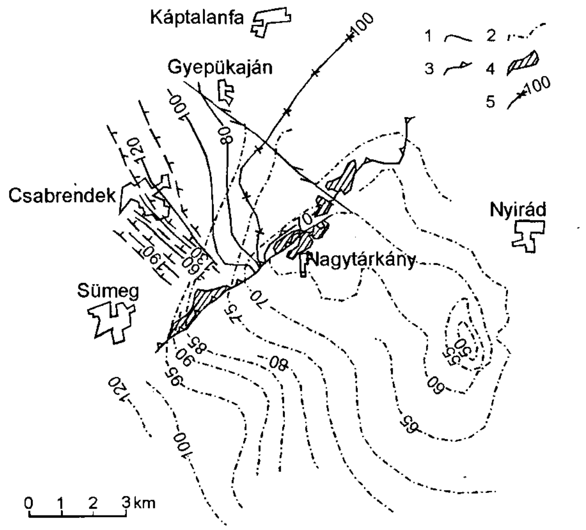

Fig. 4. Pressure contours of the karst water table in the Upper Cretaceous limestone

1. Conditions on 30th June, 1990, 2. Conditions on 30th June, 1991, 3. Boundary of the Upper Cretaceous formations, 4. Ugod Limestone directly deposited on the Upper Triassic formations, 5. Impermeable rocks below the Ugod Limestone with total thickness exceeding 100 m

4. ábra. A felső-kréta mészkőben tárolt karsztvíz nyomásszintje

1. 1990. június 30-i állapot, 2. 1991. június 30-i állapot, 3. A felső-kréta képződmények elterjedési határa, 4. Az Ugodi Mészkő közvetlenül települ a felső-triász képződményekre, 5. Az Ugodi Mészkő alatt települő vízzáró képződmények összvastagsága 100 m fölött

6. Observation of the filling process in the Nyirád cone of depression and investigation of the geological implications of this process enabled us to make important statements applicable to the whole of the TCR.

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A NYIRÁDI BÁNYAVÍZ-KIEMELÉS HATÁSÁRA KIALAKULT DEPRESSZIÓS TÖLCSÉR FÖLDTANI MEGHATÁROZOTTSÁGA NYIRÁD TÉRSÉGÉBEN

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T á r g y s z a v a k : karszthidrológia, karsztvízszint, felső-triász, felső-kréta, karbonátkőzetek, víztároló rétegek, vízzáró rétegek, vízszintes elmozdulás, Bakony-hegység, depressziós tölcsér, szinklinális, Magyarország

ETO: 556.332.46(234.373.1) 552.54.+551.763.3(234.373.1) 552.54+551.761.3(234.373.1) 556.33(234.373.1)

A Dunántúli-középhegység karszvízkészlete az ország negyven ivóvízbázisának egyike, így állapotának ismerete igen fontos. Közismert, hogy a karsztvíz szintje — elsősorban a térségben folytatott bányászat vízkiemeléseinek hatására — jelentősen lesüllyedt. Az utóbbi években a bányászati célú vízkiemelések nagymértékben csökkentek, mennyiségük ma már nem jelentős, s megkezdődött a térség rehabilitációja. A depressziós tölcsérek visszatöltődési folyamata nem pontosan az előrejelzéseknek megfelelően indult meg, ami felhívja a figyelmet arra, hogy a karsztvízáramlást és a karsztvízszintet megszabó tényezők meghatározása és befolyásoló szerepük pontosítása még további elemzést igényel. E munkához a világszerte egyedülálló feltöltődési folyamatok vizsgálata soha vissza nem térő lehetőséget nyújt.

Ezirányú vizsgálatainkat a Magyar Állami Földtani Intézetben 1991-ben a nyirádi depressziós térség visszatöltődésének tanulmányozásával kezdtük meg, abból a célból, hogy e részletesen ismert és jelenleg még sűrű észlelőhálózattal rendelkező területen minél alaposabban megismerjük a karszvízszint alakulását befolyásoló földtani tényezőket. Munkánkhoz a vízszint-adatokat a Bakonyi Bauxitbánya Kft. és jogelődje részéről dr. FARKAS SÁNDORNÉ hidrogeológus szolgáltatja. 1992-ben megkezdtük a Dorog környékén kialakult depresszió vizsgálatát is, s tervezzük valamennyi vízszintsüllyesztéssel érintett térség elemzését. Az egyes területrészeken nyert ismereteket, a megismert vízföldtani törvényszerűségek megfelelő interpretálásával, felhasználhatjuk a Dunántúli-Középhegység más, kevésbé ismert részén a vízföldtani modell pontosításához, a karszvízszint alakulásának előrejelzéséhez.

A nyirádi térség részletes elemzését az teszi lehetővé, hogy e terület és tágabb környezete földtani ismeretessége igen alapos és korszerű (1., 2. ábra).

A karsztvízszint és a földtani felépítés kapcsolata a nyirádi depressziós tölcsér területén

A nyirádi vízkiemelés következtében kialakult depressziós tölcsér területén két időpontban — a maximális depresszió időszakában, 1990. június 30-án és egy évvel később, 1991. június 30-án — mutatom be a főkarsztvízszint felszínének, illetve nyomásfelszínének képét (3. ábra).

A kissé tágabb térséget bemutató térképen a karsztvízszintek alapján több részterület körvonalazódik. ÉK-en, Ajka térségében a főkarsztvíz nyomásszintje 15–20 m tszf. Az itteni vízmegfigyelő fúrásoktól csupán egy km-es távolságban, Padragkút térségében 40–70 m-es karsztvízszint értékek ismertek. A két területrész között egy ÉNy–DK-i irányú, miocén korú feltolódási vonal húzódik, melynek mentén az eocén rétegek fölé idősebb képződmények tolódtak (2. ábra). E részterülettől DNy felé, ugyancsak kb. 1 km-es távolságra, a halimbai területrészen 1990. június végén a legalacsonyabb vízszintérték +10 m, egy évvel később –10 m volt. A szomszédos ÉK-i területtől e részterület a „padragkúti", ugyancsak ÉNy–DK-i csapású, 2–3 km-es jobbos elcsúszást okozó tektonikai vonal mentén határolódik el igen élesen. DNy felé határát a padragkúti szerkezeti vonallal csaknem párhuzamosan futó pusztamiskei horizontális elmozdulási vonal képezi, amelyhez kapcsolódva alakult ki a fiatal üledékkel kitöltött pusztamiskei süllyedék is. E szerkezeti vonaltól DNy felé helyezkedik el a nyirádi vízkiemelés depressziós tölcsérének területe.

A nyirádi térségben a karsztvízszint domborzatot legmarkánsabban a terület DK-i részén futó tektonikai vonalak határozzák meg, melyek Nyirád–Szőc térségéből indulva, egymással kb. 20 fokos szöget bezárva húzódnak DNy felé. E tektonikai vonalak, különösen a délebbre futó, igen jelentős szerepet játszottak a miocén és a pannon folyamán. A jelentős üledékvastagságú miocén (badeni és szarmata) medencék ezekhez kapcsolódva alakultak ki, alátámasztva a legújabb szerkezeti elemzések azon elgondolását, amely a délebbi vonalat horizontális elmozdulási vonalként értelmezi (DUDKO et al. 1992). E vonal K-i részéhez kapcsolódnak a Haláp és az Agártető bazaltelőfordulásai is, keleti részétől kissé délebbre pedig pannon üledékes képződmények ismertek jelentős vastagságban. A karsztvízszint alakulása e tektonikai vonal mentén csapás-irányban igen jó, rá merőlegesen erősen korlátozott vízvezetőképességet jelez (3. ábra).

A depressziós tölcsér alakját ÉNy-on ugyancsak markánsan határozza meg a földtani szerkezet. A szintvonalak sűrűsödése ugyan nem éri el a dél-délkeleten tapasztalt mértéket, de a vízszint alakulása, a szinklinális szerkezethez kapcsolódva csapásirányban szintén igen jó, rá merőlegesen korlátozott vízvezetőképességre utal. A szintvonalak sűrűsödését ott tapasztaljuk, ahol a Fődolomit fölött megjelenik a Kösseni Márga, s a Fődolomit és a Dachsteini Mészkő között, vastagsági és dőlési viszonyainak megfelelően, kb. 1 km széles sávban e képződmény alkotja a preszenon felszint, s ezzel párhuzamosan e felszín egyre mélyebb helyzetbe süllyed (2. ábra). A depressziós tölcsér Ny-i oldalát ugyancsak tektonikai meghatározottság jellemzi. Amint a DK-i és az ÉNy-i lehatároltság esetében, úgy ezen az oldalon is a +100 m-es karsztvízszintvonal a maximális érték a szorosabb értelemben vett nyirádi blokk területén. Ny-on a határoló — ugyancsak egy horizontális — szerkezeti vonal Sümegtől Ny-ra húzódik, s ettől Ny-ra alakult ki az északi részen a nagygörbői és a várvölgyi medence (az „Uzsai árok"), déli szakaszának keleti oldalán pedig a tapolcai medence süllyedéke. E tektonikai vonal a miocén során csupán felújult, keletkezése az ausztriai-pregozaui fázis idejére tehető, s a korábban már említett torlódott, felpikkelyeződött 2 km széles sümegi sáv Ny-i határát képezi. A meredekre állított sáv keleti oldalán húzódó középső-kréta korú tektonikai vonal, melynek mentén a torlódott sáv és a szabályos szinklinális szerkezet érintkezik, csupán a terület északi felében nyomozható, a déli részen elhal. Hatását a nyirádi depressziós tölcsér Ny-i oldalának északi beöblösödése jelzi. ÉK felé még ismerünk néhány e vonallal párhuzamos, rövidebb és kisebb jelentőségű szerkezetet, melyek hatása jelentkezik a karsztvízszint alakulásában. A nyirádi depressziós tölcsérben a főkarsztvízszint alakulása szempontjából lényeges földtani tényezők mind a depresszió maximuma, mind a visszatöltődés megindulása után egy évvel kialakult karsztvízszintben éreztetik hatásukat. Természetesen a későbbi időpontban, amikor a különbség már kisebb, a kevésbé jelentős hatások gyengébben jelentkeznek.

A depressziós tölcsér feltöltődése a depresszió központi részén gyorsan, nagy vízszintnövekedéssel kezdődött meg. A szűkebb értelemben vett depressziós tölcsér területén kívül azonban az első évben még igen csekély (0,5–1 m-es) vízszintcsökkenés következett be, amely a következő félévben is folytatódott. A földtani felépítéssel szoros korreláció figyelhető meg a felső-kréta képződményekben tárolt karszvíz szintjének alakulásában is. A felső-triász karsztosodásra alkalmas kőzeteire települő legidősebb karbonátos képződmény a felső-kréta Ugodi Mészkő, amely a sümegi Gerinci-kőfejtőtől K-re, Nyíres-pusztától és Nagytárkánypusztától É-ra keskeny, párszáz m-es sávban települ közvetlenül a Fődolomitra, a sáv Ny-i részén felszínre is bukkanva. E sávtól ÉÉNy felé a felső-kréta képződménysor túlterjedő települése következtében egyre nagyobb vastagságban fejlődtek ki az Ugodi Mészkő alatt az Ajkai Kőszén és a Jákói Márga Formációk vízzáró kőzetei (4. ábra). Az Ugodi Mészkő rételepülési sávjában, ahol a felső-triász Fődolomit fölött közvetlenül az Ugodi Mészkő települ, vagy a közöttük kifejlődött, vízzárónak tekinthető felső-kréta kőzetek vastagsága csekély, a „felső-kréta" karsztvízszint megegyezik a főkarsztvízszinttel.

Konkluziók

1. A Dunántúli-középhegység földtani kifejlődése és szerkezete, valamint a karsztvízszint alakulása között kapcsolat mutatható ki.

2. A Dunántúli-középhegységi nagyszerkezeti zóna fejlődéstörténetében — vízföldtani következményei miatt — két esemény különösen jelentős. Az első a késő-kréta előtt lezajlott ausztriai-pregozaui tektonikai fázishoz kapcsolódó szinklinális szerkezet kialakulás. A második az eredeti, kb. 200 km-rel Ny felé lévő képződési helyről a miocén során KÉK felé végbement kitolódás, melyhez kapcsolódva több horizontális elcsúszási vonal jött létre.

3. A nyirádi depressziós tölcsér és környezete területén a karsztvízszint igen jól mutatja e törések vízföldtani hatásait.

4. A horizontális elmozdulási vonalak vízvezető képessége e területrészen csapásirányban igen jó, rá merőlegesen erősen korlátozott. Tekintettel arra, hogy a nyirádi depressziós tölcsér és a Hévízi-tó között több horizontális elmozdulási vonal feltételezhető az „Uzsai árok", valamint a Keszthelyi-hegység peremein, e ténynek igen nagy jelentősége van a két terület közötti, máig vitatott kapcsolat megítélésében.

5. A felső-kréta Ugodi Mészkő egy keskeny sávban közvetlenül települ a fő karsztvíztároló karbonátos kőzetekre, elsősorban a Fődolomitra. Ennek vízföldtani hatása jól érzékelhető volt.

6. A nyirádi depressziós tölcsér feltöltődésének nyomon követése, s e folyamat földtani meghatározottságának vizsgálata máris több, a Dunántúli-középhegység egészét is érintő fontos megállapítás levonását tette lehetővé. E tény feltétlenül indokolttá teszi a megfigyelések folytatását, illetve a térség egyéb depressziós területeinek hasonló jellegű vizsgálatát.

ANN. REP. OF THE GEOLOGICAL INSTITUTE OF HUNGARY, 1992–1993/II: 123–130 (1999)

SEDIMENTOLOGY OF LOOSE SEDIMENTS IN THE GÖDÖLLŐ ARBORETUM: DIFFERENTIAL PORE SPACE MEASUREMENTS

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Manuscript received in 1994.

Keywords: agriculture, Pliocene, pore, pore water, sand, silt, sedimentology, water budget, water content, Gödöllő

UDC: 551.782.23(439.153) 631.42+631.43(439.153) 556.324

The authors demonstrate the interstitial structure and its laws of transmissivity through the examination of the pore space and water-storing capacity of loose sediments in the Gödöllő Arboretum represented by a model of dense space packing. Pore spaces are, in part, packed with fine grain fractions impeding the movement of water and other materials. In about a third of the examined sediment samples capillary porosity prevails, because their pores are largely filled with fine particles of solid material. Capillary porosity allows the motion of a small quantity of solid material, besides water. Meniscuses cause the formation of interstice bonds. In the majority of the sediment types, however, there are pores in which descending material transport and accumulation can take place under gravity. This is a consequence of afforestation which might restore agricultural soil destroyed in the past.

Introduction

It is well known that the behaviour of the near-surface loose sedimentary deposits is determined by the size and spatial arrangement of the solid particles making up the rock. The geometric features of the void spaces are very important, since they allow materials, mainly water, to pass through, which is essential for soil biological processes.

In the recent past, pore space studies were conducted jointly by the Geological Institute of Hungary (MÁFI) and the Forest Research Institute (ERTI) in an agro-geological model area situated in the Gödöllő Arboretum. These studies were aimed at the description of the near-surface sedimentary accumulations, mainly from the point of view of water management and of regeneration of agricultural soil.

The Gödöllő Arboretum was established in 1902 in the northern part of the hill Öreg-hegy situated between Isaszeg and Gödöllő, Hungary. After the clear-felling of the previous pedunculate oak forest the original rust-brown forest soil became exposed to erosion, and subsequently largely lost its A horizon.

Models of loose, granular sedimentary accumulations

We used Darcy's model to describe the flow of fluids in granular media. This model is based on an ideal structure of particles, essentially, an aggregate of tetrahedral or octahedral co-ordination with spherical particles equal in diameter to the mean grain-size of the sediment. In the inter-granular space, air, gas, water, oil etc. can flow in a way pre-determined by surface tension and differential pressures (HARNAJ 1972). For convenience we adopted a "model of full space-filling" which, except for grain diameter, is generally homogeneous. Here the interstitial space between particles of maximum diameter is occupied by grains in decreasing order of size (Fig. 1). The above configuration represents an ideal distribution of grains obeying an exponential function. If D_1, D_2, D_3, ... D_n represent diameters of decreasing order, the following equation can be derived:

$$D_n = (2^{\frac{1}{n}-1})D_1 \tag{1}$$

Assuming octahedral co-ordination, the number of grains belonging to the same categories of diameter in the elementary volume is given by the formula

$$N_n = 8.6^{(n-2)} \tag{2}$$

Nevertheless, void spaces cannot be filled perfectly even in the case of the smallest D_n, as shown by calculation of the limit value:

$$\underset{\lim n \to \infty}{f(n)} = \frac{8\sum 6^{(n-2)\pi}}{6(2^{\frac{1}{2}n}-1)^3 D_1^3} \approx 0.34 \tag{3}$$

Hence, about 34% of the space remains unoccupied (Table 1), and this is the so-called residual pore space (Fig. 2).

Table 1 —1. táblázat

Characteristic numerical data of the model of full space-filling of interstices
A teljes térkitöltésű modell jellemző numerikus adatai

Cumulative rank of grains A szemcse rangja n	Diameter Átmérő D_n	Number of grains in unit space Egy téregységre eső szemcsék száma N	Volume of individual grain cu.cm Egy szemcse térfogata cm^3	Volume of the grains of equal rank cu.cm Az egyenrangú szemcsék térfogata cm^3	Cumulative pore space Kumulatív pórustér %
1.	1.000	4	0.52333	4.2667	46.67
2.	0.414	4	0.03713	0.5941	39.24
3.	0.189	16	0.00338	0.3247	35.19
4.	0.044	576	0.00004	0.0256	34.86
5.	0.012	3,456	$8\cdot10^{-7}$	0.0028	34.58
6.	0.004	20,736	$3.3\cdot10^{-8}$	0.0007	34.50
7.	0.002	8,957,952	$4.2\cdot10^{-9}$	0.0004	34.48

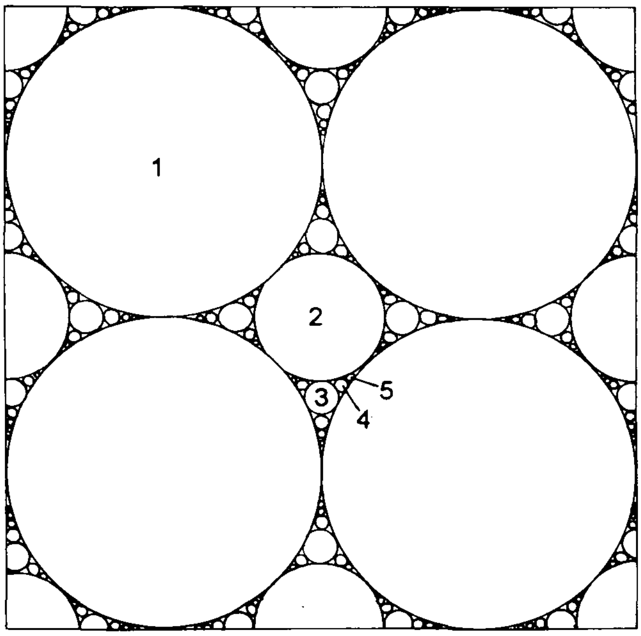


Fig. 1. Unit cells of closest packing by globular particles
N=1,2,3... grain rank

1. ábra. A teljes térkitöltés-modell elemi sejtjei
N=1,2,3.... a szemcsék rangja

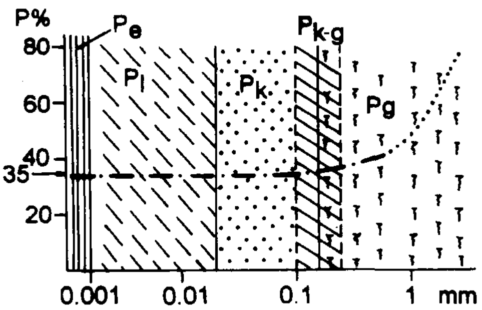


Fig. 2. Cumulative curve of pore space distribution in a model of full space-filling with the equivalent diameter of differential pore space

P_e. Pore space of tightly bound water, P_l. Space of loosed, bound water, P_{kap}. Space of capillary pores, P_{k-g}. space of capillary and gravitational movement of water; P_g. Pore space of gravity-controlled water movement

2. ábra. A teljes térkitöltés-modell pórustéreloszlásának kumulatív görbéje és a differenciált pórustérekvivalens átmérője

P_e. Erősen kötött víz pórustere, P_l. Lazán kötött víz pórustere, P_{kap}. A kapilláris pórusok tere, P_{k-g}. Kapilláris-gravitációs pórusok tere, P_g. Gravitációs pórusok tere

The model is well suited for simulating the features of near-surface arenaceous deposits where the interstitial spaces formed between the larger grains are filled with fine sand, silt, clay and organic or inorganic colloids. Fluid permeability of the medium depends on the configuration of pores and also on the types of interaction between grains and liquids (PATZKÓ 1971).

In comparing the real grain distribution with the ideal grain composition, three possible cases may be distinguished:

a) The space is occupied by grains to such an extent that it attains or surpasses the theoretical value, that is the space is entirely packed and the remaining pore space is minimal. This situation can be brought about by syngenetic processes (deposition of material of "balanced" grain-size distribution) or by epigenetic secondary processes;

b) Grain compaction is intermediate, and the space is only partly filled with solid particles;

c) The packing of individual grains remains far below the ideal value, so pore space quite exceeds the theoretical value.

The density of packing of the pore space may be estimated from the particle-size distribution (BÉRCZI 1971). To ascertain the actual geometric structure it is necessary to make differential measurements of pore space, since grain-size analyses can only be made on disturbed samples far removed from the natural, "in situ" state of deposition.

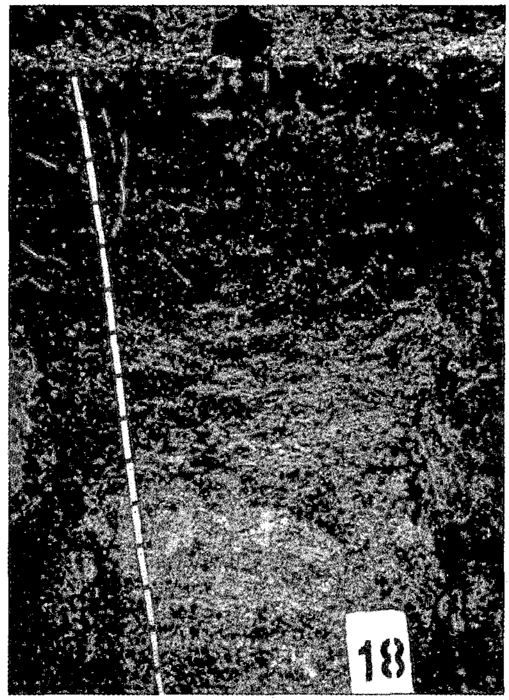
Water-capacity and the differential measurement of pore spaces in loose sediments

The geometric configuration of interstitial spaces can be defined upon data bearing on water-capacity measurements in samples of natural structure.

For this purpose, undisturbed cylindrical samples were taken from the deposits along section lines (Photos 1 and 2). Then the natural water content and the different values of

1. A thin accumulation horizon between dark sand and light clayey silt at the tree-growing site exposure G 2

1. A sötét szín — homokréteg és a világos szín — agyagos kőzetliszt között megkülönböztethető egy vékony akkumulációs szint. A G 2 sz. termőhely-feltárás szelvénye



2. Dark brown-coloured sediment grading into yellowish-grey towards the lower part of the section, brought about by enrichment of fine-grained fractions with the increase in natural water content (pit G 18)

2. Az üledékek színe a sötétbarnától (felszínközelben) a sárgásszürkébe (a szelvény alsó részében) folyamatosan megy át, ennek oka többek közt a finom szemcsés frakciók feldúsulása és a természetes víztartalom növekedése. A G 18. sz. termőhely-feltárás szelvénye

rock water-capacity were determined. In addition, grain-size composition was analysed, and some physical and chemical soil tests were also conducted, since these deposits are regarded also as "soils" in an agricultural sense. For our study, only the values of the water-capacity are of interest. These were determined by the application of A. Klimes-Szmik's method recommended by R. Ballenegger and J. Di Gleria (1962).

Samples were saturated with water for 72 hours in the laboratory by means of capillary infiltration in order to determine their capillary water-storage capacity ($V_{k\text{-}kap}$). Thereafter, full water saturation of the sample was achieved (24 hours), to calculate the maximum water-storage capacity (V_{kmax}). After completing this procedure, the sample was placed on dry sand for six days, and its weight was measured each day. Weighing on the second day yielded the minimum water-capacity (V_{kmin}) and weighing after the sixth day resulted in the determination of capillary breakpoint moisture (EKN).

For each measured category of water content there is a corresponding value of typical pore diameter. Effective diameter values were determined, in keeping with the theoretical considerations, by the method of A. Katchinsky and A. Klimes-Szmik (1962) as follows:

a) Pore space of tightly bound water (P_e). Pellicular water forms water films linked strongly together with grain surfaces by adsorption and electrostatic forces. Effective pore diameter is less than 0.001 mm in this case.

The amount of water is almost identical with that of the hygroscopic water content of "dry" sediment, and correlates with the proportion of colloidal material, i.e. the clay fraction (Fig. 3). In this pore space water plays a "mineralogical" role only, and does not take part in biological processes.

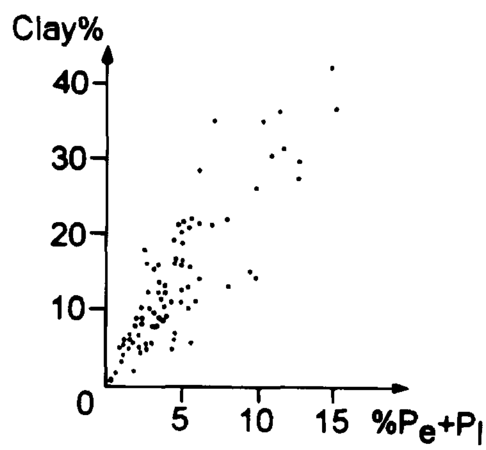


Fig. 3. Relationship between clay content and the pore space of bound water ($P_e + P_l$)

3. ábra. A vizsgált minták agyagtartalma és a holtvíz pórustere (P_e+P_l) közti összefüggés

b) Pore space of loosely bound water (P_l). This water is less strongly, but still electrostatically linked with adsorption films. The equivalent pore diameter is a few microns and, quantitatively, it equals the order of the hygroscopic value. Though to a lesser degree, however, it can be related to the amount of the fine fractions. With regard to the motion of materials in the sedimentary accumulations concerned, any tightly or loosely bound water may be considered as "dead water", dependent on the chemical hydration chemical state of minerals, but not taking part in circulation.

Loosely bound water can be utilised by micro-organisms only. From plant life, some shrubs and trees may temporarily have recourse to this humidity in case of extreme need.

c) Capillary porosity (P_{kap}) is formed between grains of medium capillary diameter (3 to 30 nm). In these interstices water movement is controlled by the forces of surface tension and capillary pressure. The direction of movement may be downward (when the dry soil receives water from precipitation or irrigation) or upward (when water is supplied from below, taking the place of water lost by evaporation), moreover water movement may be directed laterally from water-saturated zones, for example fault planes or a drain pipe. Capillary space is suitable for the movement of fluids only (air and water), and liquids can transport a minimum of solid material (colloids) to a distance equalling the grain diameter only. Thereby "meniscus cement" is formed, which contributes to the consolidation of sands (BALOGH 1992).

d) Capillary-gravity porosity (P_{k-g}) have larger diameter then the previous kind (c). Here water movement is governed by gravity and surface tension having the same order of magnitude. Organic and iron colloids can also be moved by the retreating capillary front, resulting for example in the formation of iron accumulation horizons.

e) Gravity-controlled pore space (P_g) constitutes larger voids. Their diameter corresponds to that of the sand grains, and they may attain and even exceed in number DARCY's theoretical pore space value. Here the movement of materials is controlled by gravity and is mostly directed downwards. Besides liquids, fine to medium grained materials and even the entire granular aggregate may be moved depending on the extent of saturation and mechanical forces (sand flows).

Metabolism i.e. the supply through roots of materials necessary for higher-class plant life takes place in the pore spaces under the control of gravity and capillary forces.

A characteristic aspect of the motion of materials in loose surface sediments is the transport of fine grain fractions (colloids, clay and silt) from the upper horizons downward to greater depth. These fine-grained fractions are composed of original or reworked components of the sediments, or they may be derived from inorganic and organic matter deposited on the surface (aeolian dust, plant debris or humic colloids, anthropogenic pollutants). Fertilisers, materials for soil improvement, herbicides and fungicides may infiltrate into deeper subsoil zones in a similar way.

The proportion of gravity-controlled pore spaces of capillary and pellicular waters conveys information on the inner structure of the near-surface sediments, including the extent of, or potential for soil formation.

Geological setting of the Gödöllő Arboretum

Between 1981 and 1991 we studied the northern part of the Gödöllő Arboretum. According to J. KALMÁR (1992), the area is covered by Upper Pliocene sand and silt formations. The known bed sequence of the area surrounding the hill Öreg-hegy is made up of four sand beds and three silty carbonate beds (KUTI et al. 1992). In the area of study, the Upper Sand Bed (TETHOM), the Main Silty Bed (FAGY) and the Middle Sand Bed (KÖZHOM) appear on the surface (Fig. 4).

The sand beds consist of medium-grained limonitic quartz sand with subordinate components of feldspar, muscovite and rock fragments (of andesite, granite, mica quartzite, limestone and shale), accompanied by accessory heavy minerals. The fraction finer than 0.064 mm diameter does not exceed 10%, and contains quartz, muscovite, feldspar, clay minerals of low crystallinity (illite, kaolinite), goethite, lepidocrocite, limonite and organic colloids.

The main component of the silt beds is sandy silt with quartz, muscovite, feldspar, biotite, rock fragments, heavy minerals, clay minerals (illite, kaolinite, montmorillonite) and carbonate grains. Marl, shale, calcareous silt (stone)

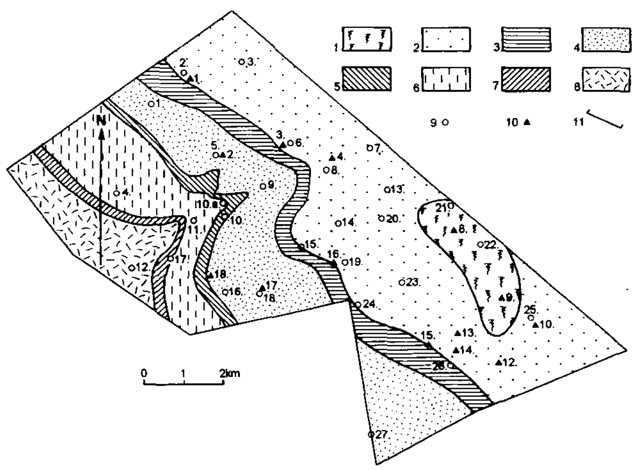


Fig. 4. Geological map of the Gödöllő Arboretum
1. Rust-brown forest soil, 2. Upper Sandbed (TETHOM), 3. Main Silt Bed (FAGY), 4. Middle Sandbed (KÖZHOM), 5. Lower Silty Bed (ALAGY), 6. Main Sandbed (FŐHOM), 7. Bottom Silty Bed (AGYFEK), 8. Lower Sandbed (ALHOM), 9. Site of agro-geological survey drilling, 10. Trial pits at tree-growing sites, 11. Boundary of the Arboretum

4. ábra. A Gödöllői Arborétum földtani térképe
1. Rozsdabarna erdőtalaj-folt, 2. Felső homokréteg (TETHOM), 3. Fő aleuritos réteg (FAGY), 4. Középső homokréteg (KÖZHOM), 5. Alsó aleuritos réteg (ALAGY), 6. Fő homokréteg (FŐHOM), 7. Fekü aleuritos réteg (AGYFEK), 8. Alsó homokréteg (ALHOM), 9. Agrogeológiai sekélyfúrás, 10. Termőhely-feltárás, 11. Az Arborétum határa

and sandstone appear with increased carbonate content in places.

The Pliocene sedimentary rocks are covered by Quaternary slope debris and patches of sandy brown forest soil, weakly humified sand and rust-brown forest soil. The mineral composition of these sediments is identical with that of the Pliocene sandy and silty strata, with the addition of a few pebbles (some anthropogenic).

Differential pore space study of the state of near-surface sediments

14 trial pits made in the Arboretum with the aim to study the water budget of coniferous and deciduous forest with trees of different age and species (SZENDREI-KOREN 1991). This research also encompassed differential pore space examinations. Several boreholes were drilled by the Geological Institute near the trial pits in different stands of trees. Samples taken from these boreholes allowed to include both sedimentary geology and soil science aspects in the characterisation of near-surface sediments.

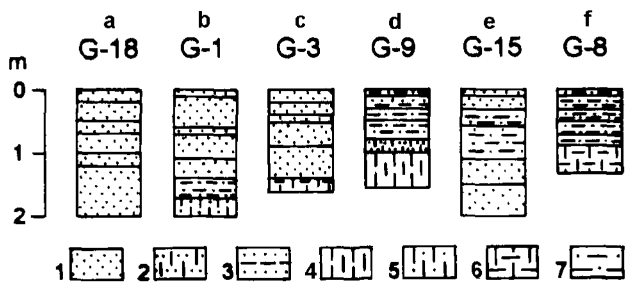


Fig. 5. Lithological section of trial pits
1. Sand, 2. Silty sand, 3. Clayey sand, 4. Silt, 5. Sandy silt, 6. Clayey silt, 7. Sandy clay, a–f. Section types

5. ábra. Termőhely-feltárások litológiai szelvénye
1. Homok, 2. Kőzetlisztes homok, 3. Agyagos homok, 4. Kőzetliszt, 5. Homokos kőzetliszt, 6. Agyagos kőzetliszt, 7. Homokos agyag, a–f. Szelvénytípusok

The sections studied in trial pits and boreholes can be classified in six groups as follows:

a) Sand only 24%;
b) Sand with some silt and clay at the bottom 32%;
c) Sand with underlying silt or clay 16%;
d) Sand covered with thin silt layer 8%;
e) Sand with thin intercalation of silt and clay 4%;
f) Sections consisting entirely of silt or clay 16%.

Two of the above types represent a silty to marly intercalation in the bed "TETHOM", and another two the silty to calcareous bed "FAGY".

Two pits (G 8 and G 16) exposed the remains of the brown and rust-brown forest soil (the original cover of Öreg-hegy) which was quite rich in organic colloids i.e. humus.

90% of the samples is sand (Fig. 6), 70% of which are pure sand. Differential examination of the pores yields further details of their sedimentary features.

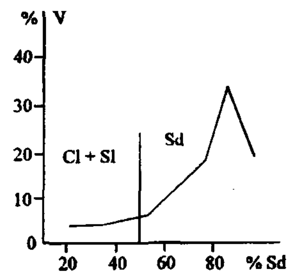


Fig. 6. Frequency distribution of sand contents in samples
cl + sl. Clayey–silty sediment, s: Sandy sediment

6. ábra. Minták homoktartalmának gyakorisági eloszlása
cl+sl. Agyagos–aleuritos üledék, s. Homokos üledék

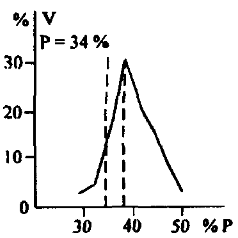


Fig. 7. Frequency distribution of pore space values (P)

7. ábra. A pórustérfogat értékeinek (P) gyakorisági eloszlása

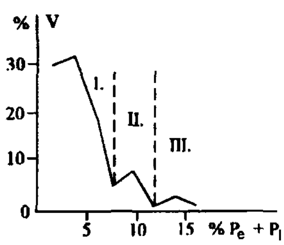
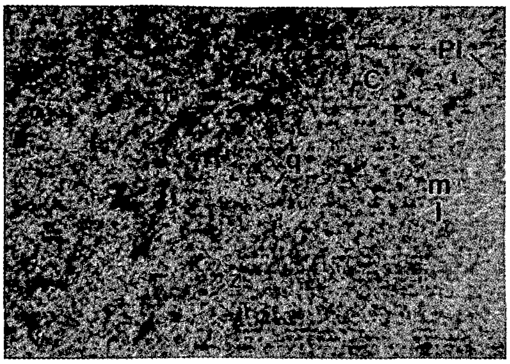


Fig. 8. Frequency distribution of bound water content in samples
I. Sand with low bound water; II. Medium bound water content, III. Fine-grained sediment with abundant water

8. ábra. Minták holtvíz-értékeinek (P_e+P_l) gyakorisági eloszlása
I. Kevés holtvízzel rendelkező homok, II. Köztes értékű holtvíztartalom, homok, finomszemcsés frakciókkal, III. Magas holtvíztartalom, finomszemcsés üledékben

The frequency distribution of pore spaces is nearly Gaussian (Fig. 7) with a value of 34% representing a frequency of 11.5%. This value points to clay/silt grain size rather than to sand (Photo 3) and it falls under the limiting value of the model we used. The predominant pore diameter corresponds to that of the "dead" bound water, so in these sediments the transmission of water or solid material cannot be expected; the bound water content exceeds 12% (Fig. 8, III).

The maximum frequency of pore space volumes over 34% is at about 38%. These samples should allow capillary water to pass through.



3. Clayey-silty marl

q. Quartz, m. Muscovite, Pl. Plagioclase, Z. Zircon, C. Carbonate. The matrix is composed largely of clay minerals. +N, 64×. Section G 16; 1.4 m

3. Agyagos-kőzetlisztes márga

q. Kvarc, m. muszkovit, Pl. plagioklász, Z. Zircon, C. karbonát. Az alapanyag nagyrészt agyagásványokból áll. N+, 64×. G 16 sz. szelvény, 1,4 m

4. Meniscus-binding with clayey-limonitic matrix at the contacts of sand-forming quartz grains

IIN, 16×. Exposure section G 2; 0.4 m

4. Meniszkusz-kötés agyagos-limonitos kötőanyaggal a homokot alkotó kvarcszemcsék érintkezési pontjain

N II, 16×. G 2 sz. szelvény, 0,4 m

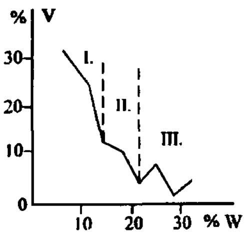


Fig. 9. Frequency distribution of momentary water content (W)

I, II and III as in Fig. 8

9. ábra. A pillanatnyi nedvesség-értékek (W) gyakoriságának eloszlása

I., II., III. lásd a 8. ábránál

In nearly a third of the samples, classified as sand by grain size, over half of the pore space is filled by solids. Any further material movement might result only in a local rearrangement of the grain structure, for instance, in the formation of meniscuses (Photo 4). This may lead to the relative stabilisation of the water content, and an increased capacity for storing water, as indicated by the distribution of natural water saturation of the samples (Fig. 9, II). Samples also contained a significant reserve of bound water (Fig. 8, II) adhering in the main to the fine fractions.

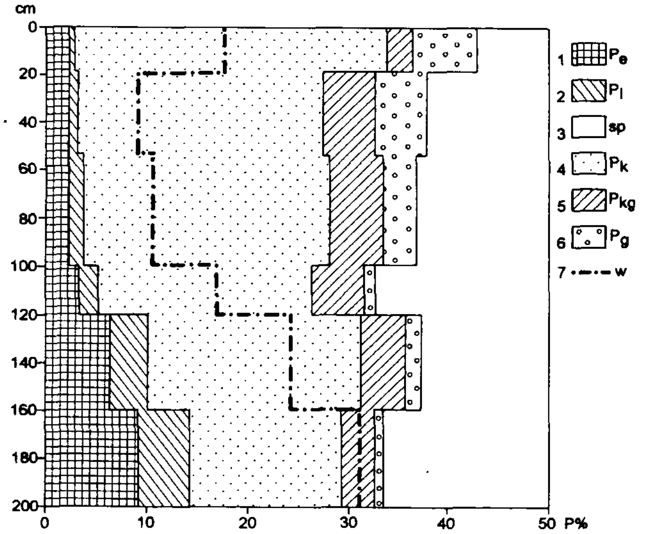


Fig. 10. Differenciated pore space distribution in samples taken at pit G 17, as a function of depth. The pore space of bound water can be seen, and the increase of water content and the decrease of pore space of gravity-controlled water movement indicates downward movement of fine fractions

w. Momentary water content, sp. Solid parts. Pore space symbols as in Fig. 2 (SZENDREI-KOREN 1991)

10. ábra. Differenciált pórustér-eloszlás a G17 termőhely-feltárás mintáiban, a mélység függvényében. Látható a holtvíz pórustere, valamint a nedvességtartalom növekedése, a gravitációs pórustér csökkenése, ami jelzi, hogy a mélységben folyamatban van a finom frakciók akkumulációja

w. Pillanatnyi víztartalom, sp. szilárd részek. A pórusterek jelei a 2. ábráéval azonosak (SZENDREINÉ KOREN 1991)

Finally, pore spaces of 50% and above, exceeding the maximum, are indicative of low water saturation in the sand interstices. Darcy's model can be applied to these samples. The spaces of capillary water and bound water are insignificant (Fig. 8, I), the water content is low, less than 14%, and water is transmitted mainly by gravity. Fine fractions of the solid particles move downwards.

In comparing the spatial distribution of these three types with the stratigraphic sections, we can see that in the upper part of the strikingly frequent type b) sections the gravitational pore space contains sand which is comparatively dry and usually passes into the sand of the saturated pore space.

Material transport in interstices and the evolution of fertile soils

Our study data reflect the present-day processes going on in such near-surface loose sediments of which the uppermost-situated fertile soil horizon was destroyed by man.

The establishment of the Arboretum has made possible the restoration of the original land conditions. Although at first the trees were planted in loose sand in many places, at cost of repeatedly renewed planting (BOLLA 1978) foresters succeeded in the afforestation, achieving the necessary density of trees. Thereby the regeneration of the A horizon commenced as early as in the '30s, thanks to the decay of fallen leaves.

Particles of small grain size have remained in place at a few sites only, where the pore spaces of sediment did not allow a downward motion of materials.

Illuvial accumulation of fine-grained fractions in the bottom horizon of the sections was found in 32 per cent of the pits made in tree-growing sites. This phenomenon has been observed mainly under stands of pine and under the 83 year old beeches. In precipitation dependent soils, in which the permanent phreatic water-base is lacking, this process has improved the water-balance, and the drought and pest resistance of the plants (PAGONYI 1980).

With continuing favourable conditions it may be expected that a well-structured fertile soil horizon will be formed, restoring the equilibrium of sedimentary structure and biological processes.

Data on pore space and water capacity of near-surface sediments are relevant for the study of interstitial structure in similar sedimentary deposits in general. As such they are of interest for a wide range of geo-sciences.

So it is well worth taking samples not just from pits and trenches but even from deeper layers, and extend the facies studies, hydrogeological and environmental surveys with these simple and cheap examinations.

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DIFFERENCIÁLT PÓRUSTÉR-VIZSGÁLATOK SZEDIMENTOLÓGIAI VONATKOZÁSAI A GÖDÖLLŐI ARBORÉTUM LAZA ÜLEDÉKEIBEN

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Tárgyszavak: mező- és erdőgazdálkodás, felső-pliocén, pórustérfogat, pórusvíz, homok, aleurit, szedimentológia, felszíni vízháztartás, víztartalom, talajszelvény, Gödöllő

ETO: 551.782.23(439.153) 631.42+631.43(439.153) 556.324

A szerzők a laza üledékekben történő anyagmozgás szemléltetésére a permeabilitást illusztráló Darcy-modell továbbfejlesztése által az ú.n. teljes térkitöltés-modellt használják. E modell a szemcsés laza üledékeket szimulálja oly módon, hogy tekintetbe veszi a homokszemcsék köztes terét kitöltő apróbb szilárd szemcsék jelenlétét egészen a kolloidális dimenziókig, és erre alapozva elemzik a differenciált pórustér-spektrum és az üledék szerkezeti–szöveti sajátosságai közti összefüggéseket.

A pórusokkal kitöltött tér elméleti alsó határa az üledék össztérfogatának mintegy 34%-a. Az alsó határ körüli pórustér a laza üledékben azt jelenti, hogy az üledék finom frakciókkal (kolloid, agyag, kőzetliszt) mintegy telített, ellentétben a részben telített vagy telítetlen üledékekkel. A jelenleg használt szemcseeloszlás csak az üledék szilárd állagú szemcséire vonatkozik, ezért a szemcseközi tér geometriájára csak a differenciált pórustérvizsgálat ad felmérési lehetőséget.

A pórustér-eloszlást természetes szerkezetű mintákon végzett vízkapacitás-mérések eredményeiből lehet levezetni. A vízkapacitás-mérések módszerének bemutatása után a szerzők definiálják az erősen és a lazán kötött víz pórusterét (P_e és P_l), mely összegezve a holtvíz pórusterét adja, továbbá a kapilláris (P_{kap}), kapilláris-gravitációs ($P_{k\text{-}g}$) és gravitációs (P_g) víz pórusterét. Az üledékben történő anyagszállítás a fluidumok és a szilárd részecskék szállítását foglalja magában. A fluidumok, különösképpen a víz mozgása létrejöhet a kapilláris és a gravitációs pórustérben; a szilárd részecskék a kapilláris pórustérben csak minimális átrendeződést szenvednek és az alapvetően deszcendens szilárd szemcseszállítás csak a gravitációs pórustérben lehetséges.

A Gödöllői Arborétum területén hét rétegből álló homokos, ill. aleuritos-karbonátos felső-pliocén rétegsor jelenik meg. A termőhely feltárások a legfelső homokréteget (TETHOM), az ezt követő aleuritos–márgás réteget (FAGY) és az alatta levő homokréteget (KÖZHOM) érintik. A pszammitok fő alkotója eredetileg egy finom–középszemcséjű kvarchomok, melyben a kőzetlisztes és agyagos frakció összege általában 10% alatt van. A vizsgált szelvények különböző sorrendben egymásra települő homok, kőzetlisztes–agyagos homok és kőzetliszt, illetve agyag rétegeket harántoltak. A szemcsevizsgálatok szerint a minták 90%-a minősül homoknak.

A pórustérfogat-értékek Gauss-típusú eloszlást mutatnak. A 34% alatti minták halmaza a teljes térkitöltés–modellnek felel meg, melyben a holtvíz által kitöltött pórustér a domináns, itt sem víz- sem szilárd szemcseanyag-mozgás nem várható. Az eloszlás maximumát képező 38%-os pórustérfogathoz a részben telített pórusterű homokos üledékek tartoznak, melyekben a víz kapilláris mozgása és a jelen lévő szilárd, kis átmérőjű szemcsék lokális csoportosulása, meniszkuszok keletkezése várható. Az üledék e része biztosítja a vízkészlet relatív konzerválását a száraz időszakban. A minták több mint felében a gravitációs pórustér a domináns: az üledék a Darcy-modell szerint viselkedik és itt létrejön nemcsak a víz beszivárgása, de a deszcendens finom-frakció szállítása is.

Az Arborétum telepítését megelőzően, főleg emberi beavatkozás eredményeként, az addig összefüggő talajtakaró nagy része lepusztult. A vizsgálataink azt mutatják, hogy a telepített erdő kifejlődését követően az addig relatíve egynemű és mobilis homokban megindult az üledék differenciálódása, a növényi eredetű vagy általuk megkötött finom frakcióknak a szelvény alsó régiójában való illuviális akkumulációja, ami a csapadékfüggő terület vízháztartására s ezáltal a faállomány további fejlődésére pozitív befolyással hat.

ENVIRONMENTAL GEOLOGICAL INVESTIGATIONS OF LAKE BALATON (HUNGARY)

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Manuscript received in 1994.

Keywords: environmental geology, limnology, Lake Balaton, Hungary, Holocene

UDC: 556.55(439:285Balaton) 504.064(439:285Balaton)

The geophysical and geological investigations carried out between 1981 and 1993 produced a number of new results for Lake Balaton. The area of the present lake contained several shallow ponds with pure and cold water which are likely to have developed at the end of the Pleistocene, between 14,500 and 15,000 BP. The inundation of the basin took place gradually, proceeding from the W towards the E. The increase in temperature and humidity of the climate resulted in a gradual increase of the water level, and the barriers separating the ponds were eliminated by erosion. The water level in the lake varied from +6 m to –1 m relative to the present day water level, as a function of climatic changes. Evidence for past levels is found in ancient shorelines of the lake. However, the raised shores do not form a stratigraphic progression by altitude.

Initially, the lake water was mesotrophic, later it became eutrophic within a short period. Lake Balaton suffered frequent changes during its geological history, but most of the time it was mesotrophic. Due to the prevailing climatic conditions, the lake was surrounded by riparian forests. The rate of sedimentation of lacustrine deposits, which was 0.4 mm/yr on average was heavily influenced by the mud agitation effect of underwater streams, the lake depth, the size of the area covered by the lake, water quality, climate, and the degree at which the shore areas were covered by vegetation.

Carbonate minerals (Mg-calcite, dolomite, calcite) form 50 to 70% of the lacustrine deposits. Most of these are autochtonous (produced by anorganic precipitation, the metabolism of phytoplanktons, or shell detritus). A lesser amount is allochtonous (waterflow load, falling dust). The remaining 30 to 50% of the mud includes siltstone, sand and clay transported by waterflows, or by the shore erosion.

The amount of mud accumulated in the area which is currently covered by water (about 2.5 to 3.0 cubic km) is approx. 1.5 times the current amount of water (about 2 cubic km). This means that the lake has entered the phase of senility.

A brief review of history of research

Lake Balaton is an important piece of Hungary's natural heritage. It is the largest shallow lake in Central Europe. Since the end of the last century, the lake and its environs have been investigated by a great number of specialists (CHOLNOKY 1897, 1918, 1920; LÓCZY 1891, 1894, 1913, 1916; ENTZ, SEBESTYÉN 1942; ZÓLYOMI 1952, 1987; BULLA 1943, 1958; BENDEFY, V. NAGY 1969; RÓNAI 1969; MAROSI, SZILÁRD 1977, 1981; MÜLLER, WAGNER 1978; SOMLYÓDY 1983; HERODEK, MÁTÉ 1984; ISTVÁNOVICS et al. 1986, 1989; MÁTÉ 1987; VÖRÖS et al. 1984) from various aspects. Despite the long series of studies contributing vast amounts of scientific data about the lake, Lake Balaton poses with increasing frequency new problems (e. g. mud deposition, eutrophication, ecological equilibrium etc.). Each of these represents a challenge to biologists, limnologists and geologists alike. To gain a better understanding of these problems scientists from different disciplines cooperated in various projects of the Geological Institute of Hungary. Investigations included the catchment area of the lake, because the current state of the lake always depends on the geological background (as a dead environment), and on the age and the ecological development of the lake. Ageing of a lake is a natural process. However, its rate may be increased by some environmental (particularly, human) factors causing the lake to change gradually to a pond, then a marsh, a meadow swamp, and finally, a meadow.

The Geological Institute has performed complex geological surveying and investigations in this area since 1965 in order to assess the current state of the recreation area at Lake Balaton including its environment, to mitigate the existing hazardous situation caused by eutrophication and mud deposition, and to reveal long-term trends. The first step was an engineering geological survey at a scale of 1:10,000. This covered 780 sq.km of the shoreline zone on which the greatest load is imposed. The survey was carried out from 1965 to 1979. This was followed by two projects running concurrently. One was the environmental geological mapping of the extended recreation area of 5200 sq.km, the other was a detailed investigation of the lake bed. The mapping was done between 1981 and 1990. The results of the mapping project have been reported in several publications (RAINCSÁKNÉ KOSÁRY, CSERNY 1984; CSERNY 1985, 1990; BOROS, CSERNY 1987; PAPP 1991). The environmental geological investigations of the lake are still in progress but are expected to be completed in the near future (MIHÁLTZNÉ FARAGÓ 1983; CSERNY 1987; BRUKNER-WEIN 1988; CSERNY, CORRADA 1989; BODOR 1987; CSERNY et al. 1991, 1992).

The aim of this paper is to give a summary of the main results of the work that has been performed at the Geological Institute since 1965, paying special attention to investigations between 1981 and 1993.

Mapping (between 1965 and 1991) and its results

The main results were summarized in a map series consisting of map sheets of scale 1:100,000, showing the environmental geology of the recreation area at Lake Balaton. This was showing all the relevant results suitable for map representation, obtained during ongoing and completed research programmes at the Geological Institute of Hungary. The basis for the compilation of this map series included environmental geological surveying, solid geology and lake bottom sediment surveys. Environmental geological surveying covered the extended recreation area around Lake Balaton, on the scale of 1:50,000, which was performed under the direction of G. CHIKÁN. Solid rock geological surveying of the Balaton Uplands was carried out at the scale of 1:10,000 by a team led by G. CSÁSZÁR. Surveying and investigation of the mud surface at a scale of 1:10,000 was done under the direction of F. MÁTÉ. A complex geological investigation of the lake bed was performed at the site by the author of this paper. The sheets in the map series were published in several variants. Variant One shows the geological structure of the shore area, indicating the type and age of each formation, and the granulometric composition of the lake bed deposits. Variant Two was devoted to engineering geology showing the engineering aspects of potential land use of the shore, and factors influencing the policy of environment protection and nature conservation such as the thickness of the lake bed mud. Variant Three shows ground-water including depth relative to the surface, hardness, the areas free of ground-water, and the organic matter content of the mud surface. Variant Four shows the chemical type and total dissolved matter content of ground-water in near shore areas, and the carbonate content of the lake bed deposits. Variant Five was devoted to agrogeology. The sheets show factors influencing agricultural value, land reclamation classification, and the manganese and copper content of lake bed deposits. Variant Six shows factors detrimental to soil fertility, and the phosphorus and nitrogen content of the top layer of the lake mud.

Each map variant contributes to solving problems of regional or local land use, environment management, agriculture, water management and environment protection.

Environmental geological investigations in Lake Balaton

The investigations of Lake Balaton between 1981 and 1993 were carried out in the following three stages:

— Between 1981 and 1986 a total of 17 boreholes were drilled into the lake bed by Aquarius Kft. and samples from each sequence were analysed in the laboratory. Complex borehole logs show the results from the sedimentological, geophysical, geochemical (organic and inorganic) tests, and mineralogical, petrological and palaeontological studies. This stage of the investigations has allowed us to take inventory of the most important features of recent lacustrine deposits and the specific features of carbonate mud.

— Between 1987 and 1989 Cuban geophysicists carried out seismo-acoustic and echo surveys in the framework of the Cuban–Hungarian technical and scientific cooperation programme. The total length of lines recorded was 370 km. The study and evaluation of reflection logs covering the entire Lake Balaton resulted in the compilation of a map showing the thickness of unconsolidated mud in the lake, and a seismo-stratigraphic structural map of the basement. This shows the spatial position of the lacustrine deposits, the mud structure, as well as the diverse morphology and structure of the basement of Lake Balaton.

— In Stage Three of the investigations, a total of 16 new boreholes were drilled by Atlas Kft. Using up-to-date isotope geochemical analyses and extending the range of paleontological analyses (palynology, diatoms, ostracods, molluscs) gave an outline of the geohistory of Lake Balaton and its environment, including the paleoecological and paleoclimatic conditions. Mud accumulation rates in the lake were measured by logging anthropogenic artificial isotopes.

Fig.1 shows geophysical survey lines and the location of the boreholes drilled in the lake.

Summary of the results of scientific studies of Lake Balaton

The most important results of studies of Lake Balaton achieved between 1981 and 1993 are as follows:

Understanding and describing the features of lacustrine deposits

The sedimentary sequence of Lake Balaton is deposited unconformably on the Upper Pannonian basement. The sequence begins with a few cm thick layer of coarse sand with pebbles. This is generally followed by a few tens centimetres thick peat bed, and finally, by carbonate mud (silt) of uniform lithology. Near the southern shore and in the

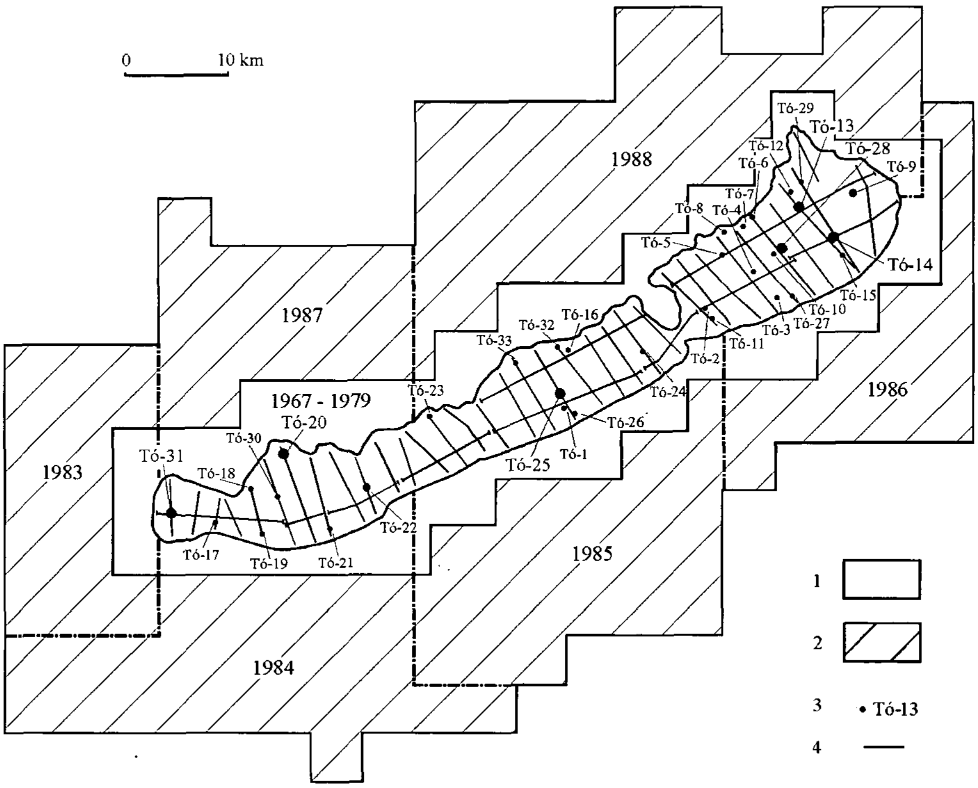

Fig. 1. Location map

1–2. Environmental geological surveys (1967–1991) at scales of 1:10,000 (1) and 1:50,000 (2), *3–4. Complex environmental geological investigations (1981 to present):* 3. Borehole drilled in the lake, 4. Line of geophysical survey

1. ábra. A Balaton környéki földtani kutatások helyszínrajza

1–2. Környezeti földtani térképezési munkák (1967–1991) 1:10 000 (1) és 1:50 000 (2) léptékben, *3–4. Komplex környezetföldtani kutatások (1981-től):* 3. Víz alatti fúrás, 4. Geofizikai szelvény nyomvonala

region of the Tihany straits the basement is overlain first by a 1 to 2.5 m thick sand bed, preceeding the carbonate mud. The lacustrine sequence is typical of the entire lake. In the lower third of the sequence there are well preserved molluscs (*Lythogliphus naticoides* FÉR., *Pisidium henslowianum* SHEEP., *Valvata piscinalis* MÜLL., *Bithynia tentaculata* L. etc.). With regard to grain size, the mud is mostly argillaceous silt with a carbonate content of 50 to 70%, that is, actually a carbonate mud. Its colour is grey, in various shades.

Our contributions to the mineralogy and geochemistry of carbonate deposits have allowed us, on one hand, to support the results obtained by G. MÜLLER (1970, 1981), and on the other hand, to make the results published by him more accurate in space and in details. As a summary, it can be stated that lacustrine carbonates have a very high primary porosity and consist dominantly of magnesium bearing calcite, and subordinately of dolomite and calcite, at some sites even of protodolomite. The constituent minerals are very unstable chemically. For the magnesium bearing calcite, the Ca/Mg ratio decreases with increasing depth, that is, the amount of Mg is increasing. The MgO content exhibits two maxima in some borehole samples. Borehole samples containing no Mg calcite at all are found in the western part of the lake, whereas borehole samples with a low Mg calcite content are observed at about the middle of the length of the lake. Borehole samples containing Mg calcite and normal calcite have been taken from the eastern subbasin. This phenomenon is due to the diluting effect of the water transported by the Zala river. Carbonate is mainly an inorganic precipitate, and subordinately, a result of processes of phytoplankton metabolism acting on shell fragments.

In the lower third of the lacustrine sequence, sulphur segregation and carbon enrichment have been observed.

The ^{18}O and ^{13}C isotope values of the carbonate of the deposits excellently reflect a gradual warming trend of the climate in the Holocene (last 10,000 yrs) (CSERNY et al. in this volume).

The age of the peat bed encountered at the base of the Holocene sequence has been tested using radicarbon dating. As indicated by these tests, the age varies from 10,500 to 12,500 BP (before 1950 datum). As shown by the results, in the area of Lake Balaton peat development began in the post-Glacial, during the Bölling warm period following the Oldest Dryas. However, this process took a long time on the lake surface and was the most widespread during the Alleröd following the Old Dryas. The youngest peat was deposited during the Young Dryas. By the evidence of radiocarbon dates of the thickest (1.2 m) peat bed penetrated by the boreholes, peat develepment lasted for 1200 to 1500 years.

Samples from a couple of boreholes have also been tested for natural isotopes. Among these the ^{40}K nuclide and the three radioactive decomposition series (uranium, thorium, actinium) have been of greatest importance. The activity values of all the studied natural isotopes show a similar tendency, namely, their values gradually decrease with increasing depth. This phenomenon is linked with a higher organic matter content of mud surface beds and its better capacity to absorb uranium and thorium. It can be observed that the ratios of the three major natural radioactive isotopes (^{238}U, ^{232}Th, ^{40}K) show good correlation all throughout which suggests that the samples from our boreholes have been undisturbed.

Anthropogenic ^{137}Cs isotope contamination has been detected in the upper mud layer. This artificical isotope can only be traced in the athmosphere since 1951, since the start of athmospheric nuclear test explosions. In the deposits, two maxima can be generally detected, namely, the year prior to the nuclear test ban in 1964, and the Chernobyl disaster in 1986. Detecting these peaks, the rate of mud development in the lake can be determined fairly well. Their lack in some samples indicates underwater wash, wheras their compensated and averaged values show underwater stirring and accumulation of reworked mud. Bioturbation by benthic fauna may lead to erroneously high apparent sedimentation rates as in borehole Tó–33. For the past 40 years, the rate of mud deposition has been fairly constant under steady hydrological conditions. We find, for instance, 14 mm per annum in the middle of Szigliget bay; whereas it amounts to 5 mm per annum at the eastern boundary of the bay. The rate of sedimentation shows both only local differences and variations in time. Based on the appearance of the contamination marker resulting from the Chernobyl nuclear disaster, the intensity of mud deposition shows a dramatically growing trend. During the past 5 years, the rate in the aforesaid regions of Szigliget bay (Fig. 1: around borehole Tó–20) were 6 cm per annum, and 2 cm per annum, respectively. In the middle of Siófok subbasin (Fig. 1: area of boreholes Tó–31, 14, 28) there are material transport processes at work which cause erosion of lake bed deposits. In contrast, in the Révfülöp subbasin (Fig. 1: around borehole Tó–25) we find accumulation above the average for the lake.

The bulk density of the lacustrine deposits gradually increases with increasing depth, from an initial value of 1.0 g/cu.cm to 1.4 g/cu.cm for argillaceous mud. For fine sand the bulk density increases from 1.7 g/cu.cm to 2.0 g/cu.cm. Their density varies from 2.2 to 2.3 g/cu.cm. Initial porosity is higher than 50% but gradually decreases to 20 to 30%, as a function of grain size and depth. Based on the consolidation index which indicates the status of a sediment, the deposit changes from a "very soft" to a "soft" status. The plasticity index of these rocks varies as a function of the clay content, reaching in some cases 100%. The higher than expected value is due to high montmorillonite content (over 10%).

Determining the spatial position of the lacustrine deposits, and the morphology and structure of the basement

The Quaternary deposits in Lake Balaton have an average thickness of 5 m. Their upper 0.2 to 0.3 m is very soft and contains much colloid material. The mud thickness in the basin varies by a wide range, since the basement morphology is also very diverse. Over some elevations of the basement, the mud thickness is reduced to 1.0 to 1.5 m, whereas in depressions it increases to 8.0 m. A maximum thickness of 10 m has been detected at the mouth of the Zala river (Fig. 1: SW to borehole Tó–31). The fracture zones of tectonically preformed meridional valleys can be excellently traced. The locations of initial "embrional" subbasins can also be observed. The average mud thickness is 6 m for the western subbasins of the lake, 5 m in the middle of the lake, and about 4 m in the eastern subbasin.

Radiocarbon dating indicates an age of 14 to 15 thousand yrs for the lake. From this figure and from data on mud thickness we get a mud deposition rate of 0.28–0.48 mm per annum, related to the entire Quaternary profile. The lower value was observed in the Siófok subbasin, whereas the higher value was detected in the Keszthely basin (Fig. 1: around borehole Tó–31).

All these can be explained by the size of the catchment area related to unit water surface, and the quantity of sediment transported by waterflows supplying the lake with water.

A brief history of geological development of Lake Balaton

The history of development of Lake Balaton can be outlined on the basis of data from the relevant literature (Lóczy 1913, 1916; Cholnoky 1918, 1920; Kéz 1931; Bulla 1943; Zólyomi 1952; Sümeghy 1958; Erdélyi 1962; Mike 1980a, b; Marosi, Szilárd 1981) and the results from our investigations performed at the Geological Institute of Hungary. We need, however, accomodate of several conflicting views.

Lake Balaton was developed on unconsolidated Pannonian deposits, with a strike parallel to the Transdanubian Central Range, between a set of intersecting fault planes. In describing the history of its geological development, we have to distinguish the Balaton Basin (Balatoni-medence) the whole of which was never covered by water and has a relatively higher elevation than the lake bed proper which was covered by water at least in periods when the level of the water in the lake was the highest. The Balaton Basin is supposed to have developed much earlier than the lake bed.

In the Pleistocene, the area of the lake bed was dominated by denudation processes, whereas in the background areas fluvial sediments and eluvial red and variagated clay beds were deposited indicating a humid climate during the warmer periods. The latter are sporadically observed in surface exposures and boreholes south of Lake Balaton.

The differential elevation of the lake surroundings continued along the main faults. These have developed earlier and were reactivated in the Pleistocene. Along the margins of blocks rising at different rates, weakened zones were formed where the Pannonian deposits became loose. By the end of the Pleistocene, the subarctic winds blowing from the N and NNW became stronger and caused deflational depressions to develop in the shadow behind the solid rock horsts of the Transdanubian Central Range. Such a hollow must have been the precursor of the lake bed which is, at present, covered by water. These deflational depressions attained a depth of up to 100 to 150 m relative to the top Pannonian level. In this area, a couple of shallow ponds were filled with pure cold water by the warming-up at the end of the Pleistocene (between 14,500 and 15,000 BP). The water in this basin system was partly of meteoric, partly of ground-water origin. The filling of ponds started from the W and proceeded towards the E.

In the Holocene, by the end of the Quercus vegetation phase (5100 yrs BP), the temperature became higher and the climate more humid. This resulted in the gradual increase of the water level, and the barriers separating the ponds became gradually submerged or eliminated by erosion. The lake was a confined system till 2000 yrs BP (at which time the Romans built a sluice). In the meantime, its depth and trophity changed several times. The fact that the water level increased for a period of approx. 600 years and then decreased for a period of approx. 1100 years is proven by raised beaches and erosion marks traced at a height of 104.6 m and 112.5 m above sea level (St.Petersburg Baltic Sea level datum) around the shores of Lake Balaton. The highest water level of the lake, and thus the highest degree of coverage by water occurred during the Fagus vegetation phase (starting approx. 2500 yrs BP). The water in the lake was oligotrophic for a short while only when the lake was formed. Later it alternated between mesotrophic and eutrophic during the geological development of the lake. Due to the climatic conditions, the lake was surrounded by riparian forests. At the beginning of the Fagus vegetation phase a considerable ecological change took place. Traces of cultivation and other human impacts can be traced to at least 2000 yrs BP.

Acknowledgements

I express my thanks to my colleagues, Ms. A. BRUKNER-WEIN, L. FARKAS, Ms. M. FÖLDVÁRI, Ms. M. HAJÓS, K. IKRÉNYI, P. KOVÁCS-PÁLFFY, E. KROLOPP, Ms. E. NAGY-BODOR, Ms. Á. RIMANÓCZY, Ms. A. SZUROMI-KORECZ, S. TARJÁN, Ms. L. WOJNÁROVITS, for the useful partial results supplied by them during the investigations.

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FÖLDTANI KUTATÁSOK A BALATON KÖRNYEZETVÉDELME ÉRDEKÉBEN

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Tárgyszavak: limnológia, környezetföldtan, Balaton, holocén

ETO: 504.064(439:285Balaton) 556.55(439:285Balaton)

A 1981–1993 között megvalósult geofizikai és földtani kutatások eredményeit összefoglalva elmondható, hogy a Balaton helyén a pleisztocén végén (14 500–15 000 BP között) több kis mélységű, tiszta és hideg vizű tavacska alakult ki. Nyugatról kelet felé a vízzel borítottság egyre később következett be. Az éghajlat melegebbé és csapadékosabbá válásával a vízszint egyre emelkedett, a tavakat elválasztó gátak az abrázió hatására fokozatosan megszűntek. A tó vízszintje, az éghajlat váltakozásának függvényében, a maihoz képest +6 m és –1 m között váltakozott. Ezekről a Balaton partján térképezett szinlők tanúskodnak, bár magasságuk alapján kortani tagolásuk nem lehetséges. A tó vize már kialakulásakor mezotróf volt, majd hamar eutróffá vált. A Balaton trofitása fejlődéstörténete során gyakran változott, de a mezotróf állapot volt a leggyakoribb. A tó környezetében, az éghajlat függvényében, ligeterdők voltak jellemzők. A tavi üledékek felhalmozódási sebességét (átlagosan 0,4 mm/év) erősen befolyásolta a víz alatti áramlások iszapmozgató hatása, a tó mélysége, a tóval borított terület nagysága, a víz minősége, továbbá az éghajlat és a parti területek növényi fedettsége.

A tavi üledék összetételében 50–70%-nyi a karbonát ásvány (Mg-kalcit, dolomit, kalcit), amely főleg autochton (anorganikus kicsapódás, a fitoplankton anyagcseréjének terméke, héjtöredék), alárendelten allochton (vízfolyások hordaléka, hulló por) eredetű. Az iszap további 30–50%-a a vízfolyások által beszállított, ill. a parti abrázió által bemosott aleurolit, homok és agyag.

A jelenleg vízzel borított területen felhalmozott iszap mennyisége hozzávetőlegesen 1,5-szerese (kb. 2,5–3,0 km^3) a jelenlegi víz mennyiségének (kb. 2 km^3), azaz a tó a természetes elöregedés fázisába lépett.

ANN. REP. OF THE GEOLOGICAL INSTITUTE OF HUNGARY, 1992–1993/II: 139–144 (1999)

ESTABLISHMENT OF THE ENVIROGEODAT COMPUTERISED DATA BASE ON ENVIRONMENTAL GEOLOGY IN THE GEOLOGICAL INSTITUTE OF HUNGARY

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Manuscript received in 1994.

Keywords: environmental geology, "ENVIROGEODAT", computerized data base

UDC: 504.06+504.5 519.688:504.5

The "ENVIROGEODAT" computerised data base management system was designed in 1992 by the Geological Institute of Hungary as part of a project on environmental geology.

The intention was to create a comprehensive system that included a range of data for environmental conservation and all the geological parameters necessary for the assessment of environmental conditions. In the course of environmental geological monitoring of potentially endangered regions the data base system would help in identifying, preventing and remedying ecological problems. The work was to proceed in three directions at once: creating the data base, modelling the environment and expert assessment. This paper is a summary of the design of the system.

Introduction

There is an urgent and ever increasing need in Hungary for the quick retrieval of geological data especially on environmental geological conditions, on geological hazards and on pollution, covering both existing and potential problems. The efficient handling of such large amounts of information requires a computer DBMS with powerful hardware.

The DBMS should preferably include a wide spectrum of environmentally related data.

In addition, the exponentially increasing number of environmental pollution incidents will require a GIS (geographic information system). Both geographical data (topography and geomorphology) and geological data (stratigraphy, hydrogeology and engineering geology) should be included. The computer processing of these data makes it possible to construct models for environmental geological processes. When the system is extended to cover geophysics, biogeography, agro-geology, engineering geology and climate data, these models would serve as starting points for the implementation of environmental research projects. These are gaining importance and become more efficient in the western world.

The computing system of the Geological Institute of Hungary is not standardised yet. Because of this the environmental geology data base has to be developed from scratch. Designing from scratch gives us a free hand, since there is no need to accommodate the requirements of any existing data base or programming system already in use or under development. On the other hand, separate development may result in incompatibility. Nevertheless, we hope that the system will be up to full capacity despite the formidable problems both in terms of hardware facilities and manpower requirements. The structure of some of the computer functions is already fairly well defined. The existing scattered applications are not forming a coherent system yet. The current stage of design aims to create a pilot data base that can form the basis of the full scale data base with added functionality. Individual data groups will be added to the data base structure in stages. The order of these operations is determined by the design considerations outlined above.

Currently available hardware is considered as a basis of further development. Increasing the capacity of the system will, of course, cause changes in the configuration. The establishment of the data base has to proceed in stages corresponding to software development and the expected expansion of the hardware.

The design presented here was created in 1992 in the scope of the Project "Examination of Hungary's environmental-geological conditions".

Structure, contents, functions and development schedule of the data base

As already mentioned in the introduction, the plan requires a structure more sophisticated than just a simple collection of data. Development activities will be directed towards three major goals: first, the establishment of a data base, second, the development of a modelling system, and third, the organisation of technical applications. It is too early to go into details of this last major goal. The draft plan contains a preliminary list of user requirements in the field of computer modelling. The data base will have to contain three major groups of information with data related to environmental hazards, topography and geology.

The plan is to create the data base in stages. Starting with a simple structure it will progressively become more sophisticated and comprehensive. Initially it will be mainly an index to the inventory of data sources but later stages will allow large scale multi-faceted retrievals. Data collection will start with the gathering of information on documented cases of pollution. This will be followed by the establishment of a national data bank.

Data on pollution and damage to the natural environment

This kind of data includes the location, type and extent of cases of pollution incidents. There is a requirement for the retrieval and selection of data according to wide ranging criteria. Direct availability of numerical data is important for statistical analysis.

Topographical data

Cases of pollution are to be displayed on maps. These maps will be accompanied by other sheets of the same area showing complementary subjects. For further interpretation the following data will also be made available: site objects (e.g. buildings), survey base data (hydrographic pattern, roads and railway lines, industrial objects etc.) and geological data (including hydrogeology and engineering geology). The system should ensure access to maps of regions and to site plans of objects of environmental impact.

Geological data

This group of data should contain all the fundamental geological (lithological, hydrogeological) information that may be of importance for the preparation of expert's reports on environmental hazards and their prevention. In a first approach, this lithological and hydrogeological information covers data related to single points (boreholes, water wells and the hydrogeological observation grid).

Pollution data, we repeat, should be available both as text and as graphic information on maps. Criteria for retrieval should include selection both by geographical coordinates and subject matter.

In order to attain the primary goal geological data will be indexed by area and subject. In perspective, since the task of environment protection involves also prediction, the data referred to have to be actively used in different works of planning, too. Thus the major part of geological data should also be rendered available for direct access.

The flexible design of the data base is not forcing hierarchical structure on the data. All elements or minor units of each information type are available directly. In this relational data base all independent items of data are referenced by keyed indexes. This allows the storage of many different kinds of data in the environmental geological data base. Some existing applications might access the data through front-end programs of data conversion. On the other hand the programming of planned data base applications becomes easier.

In our opinion, the data base of pollution case studies and hazards can be completed within three years. Part of the development will be the commissioning of the host hardware. In the first year (1993) the design of the object oriented data will be completed and a program will be developed for the loading of data into the data base. Tasks in the second year (1994) include the computer processing of topographical and thematic maps of polluted areas and the preparation of a data base management program. These tasks require a digitiser and a scanner and significant increase of storage capacity. Similar improvement in productivity is expected in the section dealing computer processed topographical data. The geological data collected in 1994–95 will be processed and integrated into the system in the third year (1995). The additional hardware requires the expansion of the computing centre by hiring of additional personnel.

Current conditions of computing capacity and manpower development are not favourable for setting up a national data bank. This is therefore one of the long range goals in the strategic plans of our institute. The effort invested in the development of a data base is most productive if the data base is used at the highest level possible.

Structure of the data base

1. Data sheet (register of objects)

Data sheets constitute the only environmental geology oriented part of the data base. If all data of the institute were kept in a common data bank we could base the processing of data on the common system, using the program to select data on pollution and hazards to the natural environment. Initially, however, the results would be poor because the available data constitutes an index (or catalogue) only and programs for interpretation are lacking.

As mentioned above, we have to start the entry of index data. There is some hope that a full-scale data base of geological information will become available soon. However, the index data are needed most for the daily tasks of our section and they would be very useful to us even without geological content.

1.1. Coding of location

We need a code system that is well known, and publicly available for everyone and covers the entire area of the country. For the time being, it seems to be best to use post codes. The four digit codes may prove occasionally inadequate where the same post code covers several jointly administered villages. So the introduction of six-digit codes seems to be inevitable in the future. Since some objects may be saddling the boundaries several adjacent villages, the system should be capable to store up to five code numbers.

1.2. Name

The official name of the object as a string of up to 100 characters.

1.3. Land registry entry number of the plot

1.4. Type

Type classification of important actual or potential sites of pollution.

1.5. Condition of the object

An informal description of an object or area e.g. relation to built-up zones, condition of building, etc. Because of the great variability of these parameters it is not worth planning separate data fields for the elements of this description. At a later stage of computer processing these data would be relegated to the status of notes or comments.

1.6. The type of land use

The original and current land use of an object may be quite different (as in the case of abandoned former military bases). Environmental geological evaluation has to consider all circumstances.

1.7. Legal ownership

For official investigations and expert advice all the data relevant to property ownership rights have to be kept up to date. These include:

1.7.1. Responsible government department

1.7.2. Tenant, managing agent, proprietor or its legal successor

1.7.3. Changes in progress

This is a data field of indefinite length ranking as "Notes". It will not be used as a retrieval key (The same way as "Type of land use", 1.6.).

1.8. Location

1.8.1. County

1.8.2. Settlement (village or town)

1.8.3. Co-ordinates of the geometric centre of the object

1.8.4. Co-ordinates of the boundary corner points of the object

This data group may contain up to 20 point coordinates, or 20 x 3 values. Should an object consists of several disconnected lots these are to be described separately especially if they serve for different purposes.

1.9. Parameters of the pollution

1.9.1. Area polluted

1.9.2. Data of pollution

This group needs a different data structure because the time distribution of the pollution is also to be recorded.

1.9.2.1. Character of pollution

The character of pollution is classified according to the national register of hazardous waste.

1.9.2.1.1. Waste of plant and animal origin

1.9.2.1.2. Waste from chemical processes

1.9.2.1.3. Herbicides, insecticides, wood preservatives and pharmaceutical waste

1.9.2.1.4. Oil industry and petroleum product wastes

1.9.2.1.5. Waste from the production and use of organic solvents, paints, lacquers, adhesives, putties, glues and resins

1.9.2.1.6. Plastic and rubber waste

1.9.2.1.7. Textile waste

1.9.2.1.8. Other chemical process waste

1.9.2.1.9. Other special waste

This is the top-level classification of pollutants. The detailed classification is reached through a hierarchy of menus. The aim is to classify the type of hazard. The actual polluting substance is recorded in subsequent fields after the classification.

1.9.2.2. The measured extent of pollution

This data set is stored in a separate table. Rows of this table will contain actual measurement values of chemical substances at reference sites. The table will have 10 rows, so up to 10 different substances can be recorded. Each of the columns of the table will contain the array of concentrations measured at a given date. The unit of measurement will be entered in a separate field.

Potential uses of the data include:

— Location classification by post codes allows cross referencing between these and other groups of data (maps, borehole logs etc.) which may be entered later. A topographical index map may be created for each town or village showing the different objects e.g. boreholes.

— The classification by pollutant may be used as the basis of statistical reports and comprehensive studies of individual counties or the whole country. In addition, retrieval by type should facilitate investigation of case studies involving similar pollutants.

— Retrieval by location or area should be possible. It should be possible to formulate queries containing both geographic and other retrieval criteria like land use.

— Retrieval should be possible by pollutant class either as the single key or in combination with geographic location code.

— Other environmental hazards than pollution may be covered at a later stage. These include problems for construction and agriculture like mining subsidence in areas affected by underground or open cast mining. The data base program should be capable of further extension.

— Pollution is by far the most important environmental hazard for us nowadays. Incorporation of data on soil erosion and landslides in the data base is not required in this stage.

2. Topographical maps

Maps and survey plans of objects form one of the most effective form of graphic visualisation.

The base map should be available in digitised form allowing map transformations such as scaling and compositing. The area of Hungary is fully covered by published topographical maps at scale 1:25,000 and 1:100,000. To our knowledge coverage at larger scales is incomplete. Small scale maps are good for generalisation but do not show local details near the objects of our interest. For this, a scale of 1 : 10,000 would be required.

Such detailed survey of the whole of Hungary is, however, beyond the remit of the institute, let alone our project. At present we should concentrate on regions already suffering environmental damage. If complete coverage of the country is considered as a long term goal then the outlook is hopeful.

2.1. Codes of site identification

Each map should be identified by a single key code. As discussed above (1.1.) the retrieval key is the post code number. Accordingly, every village should possess its own map. The post code connects the area of a village and the objects that are located in the area. The retrieval of map sheets will require the handling of up to five code numbers. This means that up to five maps will be retrieved for a given object. Each code will refer to the map of a different village.

The contents of the base map and the thematic maps should be kept separate. The two groups of data are of equal rank. If a retrieval query is aimed at retrieving maps of an area then the map sheets are the result of the query and the retrieved set of data does not include other kinds of information associated with the area. On the other hand if the query aims at an industrial object (economic unit) then the maps returned by the query should contain specific information about the particular site.

2.2. Geographic region code

In theory, you can reduce a digitised map without limits. Digitised maps can therefore be used to study areas of a wide range of sizes. Retrieval of data for administrative regions (e.g. counties) is possible by using post codes. Physical geography regions may require the use of another code (e.g. the so-called "Little-region code").

2.3. Geological unit code

Future demand to retrieve by geological regions may require the coding of entries by geological regions.

2.4. The smallest enclosing quadrangle

Several maps may have to be processed and displayed on to the screen together. The assembly of composite maps should be an automatic function. Provided there are common reference points (and maybe some overlap) between the individual sheets this presents no problem. In our opinion, however, the magnitude of the area of a village can be determined easily enough with the Hungarian national grid (EOTR) coordinates of four points. These points can also serve as reference points for the pasting of adjacent sheets.

2.5. Map elements

2.5.1. Contours

The study of the immediate neighbourhood of objects requires large scale maps. The digitisation of maps of 1 : 1000 scale or larger is not currently feasible. Thus, if necessary, enlargements should be made from 1:10,000 scale maps. Consequently, all the contours of 1:10,000 scale maps have to be digitised. Occasionally the contours can be omitted from plotting e.g. in the case of displaying the entire area of a region or a county.

2.5.2. Spot heights and bench marks

2.5.3. Hydrographic pattern

2.5.4. Road system

2.5.5. Built-up area

2.5.6. Boundaries of geological formations

It is a practical requirement that each category of the map elements mentioned above could be used separately or in combination with others. In addition, maps should show the investigated industrial objects, boreholes, water wells and different kinds of water works.

3. Special geological information

On certain areas there are more data available than a single map could display. On the other hand these data may constitute different approaches to the description of natural phenomena of the area (soil science, morphology, engineering geology etc.), and the information they convey should not be ignored.

A compromise solution is to keep these data archived and indexed in the project files but they do not need to be digitised. Computer scanning of the data seems to be simplest option which allows the static computer display of map documents. Of course, scanned documents require a lot of storage space.

It goes without saying that this solution is not perfect and should be used in conjunction with the indexing and abstracting of information. This requires its own data structure which can be based on the existing classification developed for manual records (see paragraphs 3.2 to 3.9).

3.1. Location Code

This code is based on the post code with further digits added. A single code is sufficient since this set of data fields is tied to the topographical map of a given village.

3.2. Geomorphological conditions

Brief descriptions about the subject in note form.

3.3. Spatial position and homogeneity of formations, stratigraphic conditions

3.4. Lithology (sedimentary, volcanic)

3.5. Granulometry, structure and soil mechanical conditions

3.6. Tectonic conditions

3.7. Surface movements

3.8. Hydrogeological conditions

3.9. Seismic hazards

3.10. Economic geology, mineral occurrences

3.11. Bibliography of thematic maps

4. Geological boreholes

All boreholes and wells have to be recorded in the computer file: boreholes drilled for regional surveys, structural and stratigraphic research and exploration for mineral deposits or subsurface waters, irrespective of their depth of completion. On occasion, surface exposures and underground workings could also be entered.

4.1. Location code of site

4.2. Well (or pit) name

4.3. Location of borehole (exposure)

4.4. Depth of borehole

4.5. Ground water data

4.6. Stratigraphic log

4.7. Reports

5. Water wells

The structure of this set of data fields is essentially the same as that of the geological boreholes. Some exploration wells converted to production wells may appear in both files.

5.1. Location code of site
5.2. Well name
5.3. Type of well
5.4. Location of well
5.5. Depth
5.6. Filtered formations
5.7. Ground water pumping tests
5.8. Analyses of water quality
5.9. Reports

6. Springs
    6.1. Location code of site
    6.2. Name of spring
    6.3. Type of spring
    6.4. Spring catchment area for drinking water supply
    6.5. National grid co-ordinates (EOTR) of spring
    6.6. Reservoir rock
    6.7. Analyses of water quality
    6.8. Reports

7. Surface water stations
    7.1. Location code of site
    7.2. Name of station
    7.3. Type of station
    7.4. National grid co-ordinates (EOTR)
    7.5. Altitude of water level
    7.6. Velocity of stream
    7.7. Spring discharge
    7.8. Temperature
    7.9. Analyses of hydro-chemical data

Potential linking of data groups

We mentioned in the introduction the development potential of the data base and the expected rewards. The data groups listed in the preceding sections will serve as an extended index to the available data assuming the implementation of a suitable retrieval system. Even this would represent significant improvement compared to the current situation. The question is whether this indexing, extended to cover the whole of the country, will pay for itself. This partly depends on the initial availability of software and the possibility to reuse the software in the context of the more sophisticated applications of the future.

We have no current experience of using computer applications programs in the fields of environmental geology or nature conservation. Thus it is difficult to forecast the future demand for data by computer models. We think that there will be a need for flexible graphics plots. Besides topographic and generalised base maps of varied contents and size, we need different kinds of geological (lithological, hydrogeological) sections and diagrams.

Hydrogeological and pollution plots are likely to be needed showing the change of element concentrations and the amount of pollutants as a function of time. Furthermore, cross plots are needed to show the variations in such concentrations as a function of water yield. Other diagrams will deal simply with the spatial extension of pollution. These plots lead to statistical analysis and to the use of geomathematical methods.

Luckily, there is already a good range of software packages available. The number of applications is steadily increasing. It may be that the data structure required by these programs will satisfy future requirements, too. It is hoped that the data base can be linked to these high-performance processing programs through dozens of data transformation modules. Such developments may eventually lead to an expert system.

Setting up of the Environmental–geological data base

Stage 1
Pollution data (Environmental data base)
Location (administrative subdivisions, grid co-ordinates)
Object
— type
— legal status
Pollution
— precise location, extent
— pollutant classification
— amount as a function of time

Stage 2
Level 1
Topographic base data (GIS)
District map (digitised)
Relief
hydrography
geological maps
geomorphological elements
geophysical data
Level 2
1. Actual (Computerised register of actual incidents of environmental pollution)
2. Potential (Monitoring of environmental geological hazards for the whole of Hungary)
   Parallel component data bases (data groups that can appear independently or joined by relationships)

Stage 3
Geological data (Geological data base)
Boreholes and sections — Lithology
Sampling sites (boreholes, wells, springs, surface waters) — geochemical analyses

Stage 4
Environmental geology models
Models of natural processes in affected terrains
Modelling of pollution
Trend analysis
Computer modelling of preventive measures
Technical data can be linked with graphic base as required.

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ENVIROGEODAT SZÁMÍTÓGÉPES KÖRNYEZETFÖLDTANI ADATBÁZIS KIÉPÍTÉSE AZ INTÉZETBEN

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Tárgyszavak: környezetföldtan, „ENVIROGEODAT", adatbázis

ETO: 504.06+504.5 519.688:504.5

A Magyar Állami Földtani Intézet környezetföldtani kutatási projektje keretében 1992. évben kidolgozták az "ENVIROGEODAT" számítógépes geoinformatikai rendszer alapját képező adatbázis tartalmi és felépítési tervét.

Az egyszerű adatbankot messze meghaladó a rendszer, mert az általános környezetvédelmi alapdatokon túlmenően a geológiai paraméterek mindazon fajtáira kiterjed, amelyek a környezetállapot általános meghatározását, illetve a bekövetkezett ökológiai haváriák felderítését és elhárítását lehetővé teszik, a potenciálisan veszélyeztetett régiók rendszeres környezetföldtani megfigyelése mellett. A rendszertervezet szükségszerűen három szintű: adatbázis létrehozása, modellalkotás és környezetföldtani szakértői rendszer működtetése. A végleges kiépítés után a rendszer a környezetszennyezések okainak feltárására, a folyamatok időben és térben történő egzakt deffiniálására és a mentés-elhárítás módozataira fog eszközül szolgálni.

A feltöltés, tesztelés és totális működtetés időben négyéves periódust vesz igénybe. A cikkben a szerzők átfogóan ismertetik a rendszertervezetet.

ANN. REP. OF THE GEOLOGICAL INSTITUTE OF HUNGARY, 1992–1993/II:145–157 (1999)

DEVELOPMENT OF THE SAGUS PROGRAM SYSTEM AND ITS POTENTIAL USES IN APPLIED GEOLOGY

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Manuscript received in 1994.

Keywords: SAGUS program system, geological apply

UDC: 519.688:550.84 519.688:631.42

In recent years, the Geological Institute of Hungary developed a program system for the analysis of the granulometric composition of unconsolidated sediments. An essential requirement was to provide a technique for the processing of measurements on unconsolidated sediment samples which allows the use of correct statistical algorithms especially suitable for small data sets. Further requirements included analysis of individual samples (quantitative analysis), comparative analysis of sample sets, and their genetical analysis (qualitative analysis) as well.

Program outputs, computed from measurement data, include:

— Graphic cumulative curve, including statistical parameters;
— Average cumulative curve for a set of sample analyses;
— Mode test of density functions;
— Nonlinear mapping analysis.

We express our thanks to M. LANTOS, Z. PÁSZTOR and J. KALMÁR for frequent consultation on technical issues, to Prof. Z. BORSY and Dr. P. SÜMEGHY (Kossuth Lajos University, Debrecen) for the driftsand and loess data sets made available to us, and finally, to L. KUTI for guidance and help in the program development.

The mathematical basis of SAGUS, including recent developments

by L. VALKAI

Mathematical fundaments and spline interpolation

SAGUS (System for Analysis of Granulometric Data of Unconsolidated Sediments) is a computer program system for the complex analysis of geological data that realises a set of known mathematical algorithms; some of them in modified or enhanced form.

A guiding principle in building the system was a balanced treatment of the various procedures each having different sensitivity and initial conditions. This required a framework enabling combined and unified application of mathematical algorithms otherwise developed for different purposes.

The procedure determines the continuous distribution function (cumulative curve) from the data of a sample, obtained from granulometric measurements. The initial function (PÁSZTOR 1988) is a step-type, discrete function of the measurement results, giving the relative weights with discrete fraction boundaries.

Let

$$x_0 < x_1 < x_2 < \ldots < x_{n-1} < x_n \qquad (1)$$

be the fraction boundaries; and

$$g_1, g_2, g_3, \ldots, g_{n-1}, g_n \qquad (2)$$

the relative weight of the fractions.

Generate a distribution function with the following properties:

— Its limit is 0, when the value of the independent variable approaches $x \rightarrow -\infty$;

$$\lim_{x \to -\infty} F(x) = 0; \qquad (3)$$

— Its limit is 1, when the value of the independent variable approaches $x \rightarrow +\infty$;

$$\lim_{x \to +\infty} F(x) = 1; \qquad (4)$$

— The function is monotonic non-decreasing between the end-points:

$$F(x_a) \leq F(x_b); \qquad \text{if } x_a \text{ is less, than } x_b \qquad (5)$$

— Exactly honours the measurement data points:

$$F(x_i) = \sum_{k=1}^{m} g(x_k); \qquad (6)$$

where: $1 \leq i \leq n$; $1 \leq k \leq m$.

The equation of conditions of the distribution function for the density function is as follows:

$$\int_{x_{i-1}}^{x_i} f(x)\,dx = g_i \qquad \text{where:} \quad 1 \le i \le n. \qquad (7)$$

For linear interpolation, the average density function is as follows (GYURICZA et al. 1987):

$$h(x) = \frac{g_i}{x_i - x_{i-1}} \qquad \text{where: } x_{i-1} \le x \le x_i. \qquad (8)$$

The degree of smoothness can be improved by creating intermediate breakpoints within the interval. After transforming of the function and merging the original and intermediate breakpoints, the new limit points will be:

$$z_0 < z_1 < z_2 < \ldots < z_{m-1} < z_m. \qquad (9)$$

The approximate distribution function is given by Fig. 1.

$$F(x) = \int_{-\infty}^{x} h(z)dz = \int_{z_0}^{z_{k1}} h(z)dz + \int_{z_{k1}}^{z_{k2}} h(z)dz + \int_{z_{k2}}^{x} h(z)dz. \quad (10)$$

Transforming the density function [f(z)], the distribution function is as follows:

$$F(x) = \frac{1}{2} \cdot \frac{f(z_{k+1}) - f(z_k)}{z_{k+1} - z_k} \cdot (x - z_k)^2 + f(z_k) \cdot (x - z_k) + S_k \quad (11)$$

where: $$S_k = \sum_{j=1}^{k} c_j; \qquad (12)$$

and $$c_j = \int_{z_{j-1}}^{z_j} f(z)dz = \frac{f(z_{j-1}) + f(z_j)}{2} \cdot (z_j - z_{j-1}) \qquad (13)$$

c_j — an integration constant.

The spline–interpolation approximate function of second order is easily programmable (GREVILLE 1969), and the inverse function is also simple to calculate (PÁSZTOR 1988).

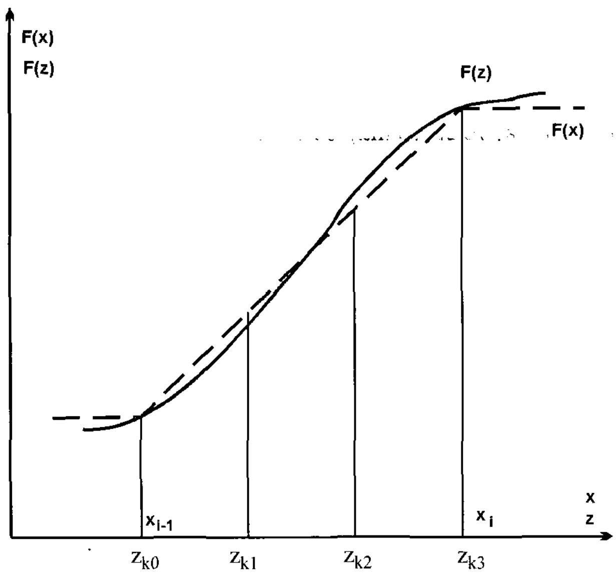


Fig. 1. An intermediate portion of a function, with a coarse approximation: F(x); with a smoothed, spline approximation: F(z)

1. ábra. Egy közbenső függvény szakasz durva közelítéssel: F(x) és simított spline közelítéssel: F(z)

Advantages from the application of the approximate method outlined above are as follows:

— Applicable as a basic algorithm, for further analyses;

— Allows for the calculation of the graphic pattern of the distribution function (cumulative curve) with an accuracy of ‰ (thousandths);

— Provides an opportunity to use algorithms requiring a considerable amount of data;

— Calculations according to the percentile method can be made more precise;

— It allows for the elaboration of new statistical measuring figures.

Eventual restrictions include:

— The results cannot be more accurate than the accuracy of the measurement data;

— Being an approximate method, thus, a corresponding accuracy of the result can be expected.

Major graphics of results

The SAGUS program system supplies the results mainly by means of graphic diagrams, and by displaying data lists (VALKAI et al. 1991).

The major services are as follows:

— Graphic cumulative curve (calculations in steps of 0.1%, displaying in steps of 0.5%), with statistical data according to the percentile calculations, with the grain diameter measured in Phi, or mm units (Figs. 2/a and 2/b). Conversion values for grain diameters are included in Table 1;

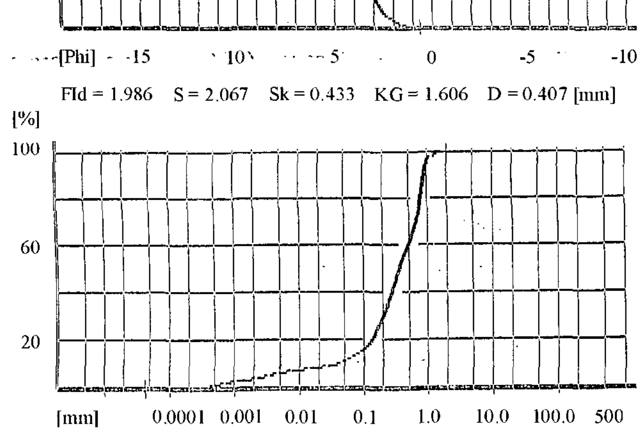


Fig. 2a–b. Cumulative curve with statistical data; a) unit of diameter — Phi, b) unit of diameter — mm

FId. Average grain size of Phi unit, S. Standard deviation, Sk. Slope, KG. Peakedness, D. Average grain size of unit of mm

2a–b. ábra. Kumulatív görbe statisztikai adatokkal (a. Φ-skálával, b. mm-skálával)

FId. átlagos szemcseméret Φ-értékben, S. Szórás, Sk. Ferdeség, KG. Csúcsosság, D. Közepes szemcseátmérő mm-ben

Table 1 — 1. táblázat

Φ/mm and vica versa conversion of grain diameter — A szemcseátmérők Φ és mm mértékegységű értékeinek átszámításához

Φ	mm	Φ	mm	Φ	mm
-4	1,600 * 10^{+1}	1	5,000 * 10^{-1}	6	1,563 * 10^{-2}
-3	8,000 * 10^{+0}	2	2,500 * 10^{-1}	7	7,813 * 10^{-3}
-2	4,000 * 10^{+0}	3	1,250 * 10^{-1}	8	3,906 * 10^{-3}
-1	2,000 * 10^{+0}	4	6,250 * 10^{-2}	9	1,953 * 10^{-3}
0	1,000 * 10^{+0}	5	3,125 * 10^{-2}	10	9,766 * 10^{-4}

— The average cumulative curve of samples corresponding to the same test scale, including the average values of the percentile statistical data, and the envelope curves marked min. and max., corresponding to the minimum and maximum grain size, respectively, for each percentile value (Fig. 3). The unit for grain diameter can be either Phi, or mm;

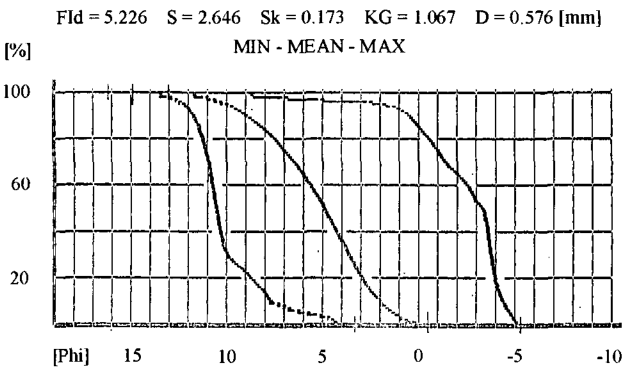


Fig. 3. The average cumulative curve for samples corresponding to the same portion of examination, including the average values of statistical data and, at each per cent value, the envelope of the minimum and maximum grain size (For the legend see Fig. 2.)

3. ábra. Egy szitasoron vizsgált minták kumulatív átlaggörbéje a minimum és maximum burkológörbével (A jel-magyarázat az előzővel egyező.)

— A C/M diagram with log/log coordinates, made according to a method by PASSEGA (1964), with a separate on-screen data listing for identification;

— The graphic displaying of measurement results (statistical parameters, petrological grain size ranges) by borehole log;

— A graphic figure of NLM (non-linear mapping) two-dimensional diagram plotted on the basis of an algorithm by SAMMON (1969), including separate screen data lists for identification.

Modified calculations

In addition to the convential method, also another, refined method can be used to calculate the statistical parameters of grain distribution. This method is ensured by calculating the points of the cumulative curve at each step of 0.1%. Based thereupon, and upon the conventional methods, the statistical parameters of our own (Sagus) have been worked out. These parameters are much more sensitive due to the refinement.

The average grain size, according to MCCAMMON (1962), is as follows:

The same, according to the Sagus method, is:

where:

$$D=\frac{\Phi_5+\Phi_{10}+...+\Phi_{90}+\Phi_{95}}{19} \qquad (14)$$

$$D=\frac{\delta}{I_v - I_0 + \delta} \cdot \sum_{\delta_i=I_0}^{I_v} \Phi_i \qquad (15)$$

I_0 — the initial (first) percentage index

I_v — the final (last) percentage index

δ — step value (0.1, or greater)

Φ_i — grain size value corresponding to the particular percentage index.

The slope parameter, according to FOLK and WARD (1957), is:

$$S_k=\frac{\Phi_{84}+\Phi_{16}-2\Phi_{50}}{2\,(\Phi_{84}-\Phi_{16})}+\frac{\Phi_{95}+\Phi_5-2\Phi_{50}}{2\,(\Phi_{95}-\Phi_5)}. \qquad (16)$$

The slope value that can be calculated by using the Sagus method is as follows:

$$S_{ks}=\frac{\delta}{I_v - I_n} \cdot \sum_{\delta_i=I_n} \frac{\Phi_t+\Phi_b-2\Phi_n}{\Phi_t-\Phi_b} \qquad (17)$$

where:

I_v — the final (last) percentage index

I_n — the nominal (50%) percentage index

δ — the step value (0.1%, or any greater value)

Φ_t — grain size value (in Phi unit) assigned to the nominal index by a shifting of $+(k-\delta)$

Φ_b — grain size value assigned to the nominal index by a shifting of $-(k-\delta)$

Φ_n — grain size corresponding to the nominal index.

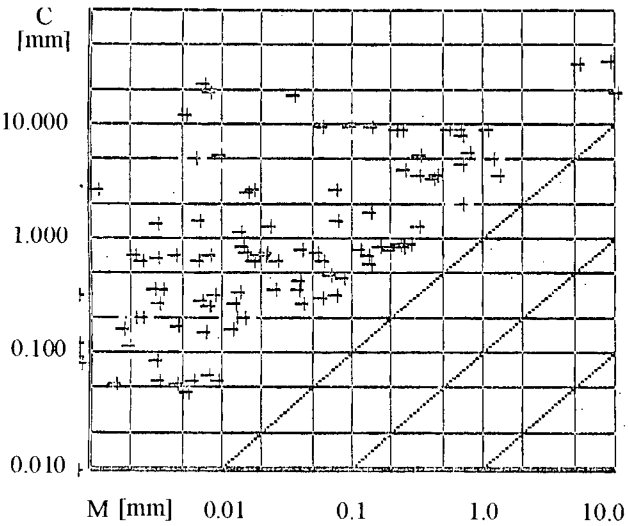
As shown by the above relationships, any portion of the cumulative curve may be used as a basis for the calculation, with finer steps than those of the conventional formulae.

An opportunity offered by Sagus system was also made use of in the plotting of a new graphic diagram. Grain size values of 99% are represented vs grain size correponding to 50%, in a C/M diagram according to PASSEGA. As an analogy to it, an M/L diagram in which the grain size of 50% is represented as a function of grain size corresponding to 1%, was developed in the Sagus system.

For comparison, the diagram of results based on 100 samples, according to both methods, is enclosed in Fig. 4.

Separating the composite density function

The granulometric composition distribution of unconsolidated sedimentary rocks may be a resultant of several distributions each developed in response to a homogeneous process. To make clear the examinations based on measurement results concerning granulometric composi-



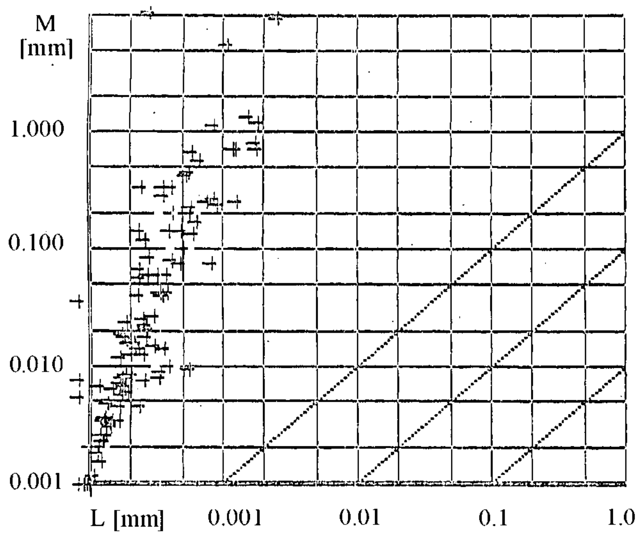


Fig. 4a–b. Results from the analysis of a data set of mixed character, consisting of 100 samples
a) in a C/M diagram according to the method by PASSEGA, b) in an M/L diagram of the Sagus system (it is in line with the method by PASSEGA)

4. ábra. 100 darab, vegyes genetikájú minta kiértékelése C/M diagramban, PASSEGA-féle módszerrel [a], ill. M/L diagramban, Sagus-rendszerben (a PASSEGA-módszerrel analóg) [b]

tion of rock samples, it is necessary that the combined distribution can be separated to constituents. The separating procedure is an iterative one based on substituting constituents (ZÁMORI 1969), based on the principle of compensation according to the method of least squares.

Assuming that the substituting constituents (RÉNYI 1950) have a normal distribution with a logarithmnic scale, the equation for the function (DETRE et al. 1992) is as follows:

$$f(x)=\frac{1}{\sigma\cdot\sqrt{2\pi}}-e^{\frac{(x-x_e)^2}{2\sigma^2}} \tag{18}$$

where:

x — independent variable (log grain diameter)

x_e — expected value of the variable

σ — standard deviation.

The integrated procedure has been worked out on an algorithm by M. LANTOS, a detailed description of which is found in the relevant literature (DETRE et al. 1992).

The iteration algorithm needs the initial parameters of the constituting functions by each mode (expected value, standard deviation and function amplitude), and, according to M. LANTOS, as a matter of importance, 8 to 10 measurement values with equidistant sampling.

In the procedure realized in the Sagus system, the application of spline-interpolation has allowed us to considerably reduce the requirement for measurement data.

The developed program version also allows for the separation of multi-mode composite functions. A typical example of it is shown in Fig. 5. The program also promotes the separating procedure by graphically giving the residual function after each time the initial parameter of a substituting constituent is entered.

When working out the system, all chances ensured by the program as secondary results could also be utilized. As a result, a new, statistical type parameter, namely, an asymmetry factor referred to as As, typical of asymmetry, could be worked out.

$$As=\frac{1}{S_T}(S_C-S_L) \tag{19}$$

where:

$S_C=\int_{x_e}^{+\infty} f(x)dx$ (20): the amount of the upper range;

$S_L=\int_{-\infty}^{x_e} f(x)dx$ (21): the amount of the lower range;

$S_T=\int_{-\infty}^{+\infty} f(x)dx$ (22): the amount of the entire range.

With discrete substituting values, the ratio of ranges is as follows:

$$S_C=\int_{i=x_e}^{x_H} f(x_i) \tag{23}$$

where: x_H — the greatest, still calculated grain size;

$$S_L=\int_{i=x_L}^{x_e} f(x_i) \tag{24}$$

where: x_L — the smallest, already calculated grain size;

$$S_T=\int_{i=x_L}^{x_H} f(x_i). \tag{25}$$

X_e represents the imaginary symmetrical axis of asymmetry which corresponds to the expected value of the single lognormal mode automatically imaged on the measurement results. The relative weight ratio of the upper and lower ranges has to be compared thereto.

Features of the SNLM algorithm

The NLM algorithm allows for an easy representation of the multi-parameter individuals to be measured, and reveals differences meaning a good basis for comparison (Ó. KOVÁCS 1987) and represents a procedure that has also been used in geological examinations for a long time (HOWARTH 1973).

However, it provides no chance (since the algorithm is not developed for it) to compare two, separately examined measurement groups without any further examinations, and to compare the NLM coordinates. When checking the operation of the NLM algorithm integrated into the Sagus program, it has been found so that the aforesaid disadvantage needs a reduction.

Our aspects concerning the modifications are as follows:

— The Sagus program system has been developed for the granulometric composition analysis of unconsolidated sedimentary rocks, therefore, the typical data of the samples, including statistical parameters, and their extreme values can be regarded to be known;

— In the known range of data, an n-dimensional space has to be determined (to create) and the test range should be marked out within this space;

— To calculate the point-system matching the boundary surfaces of the range to be examined;

— Using the coordinates of the system of points, to define the range to be examined, as an n-dimensional subspace;

— To study each sample separately, in this strained range of examination.

The implemented procedure is as follows:

— The coordinates of the system of points, straining the examination range has been made to be an integral part of the program;

— Using the coordinates, a scale system has been built up which, in our conception, ensures that two separately examined sample can be compared (making it measurable);

— The program will integrate, by sample, the data of each sample, into the strained examination range and will perform, for each sample, the 2-dimensional calculation of coordinates according the NLM algorithm;

— The program monitors, by a continuous error code calculation, the acceptability of the series of analyses, and confirms this value on the graphic display of the results.

The 2-dimensional coordinates calculated in the above way, strictly by sample, allow for the plotting of graphic diagrams. This is the scaled Sagus NLM, that is, SNLM (Fig. 6).

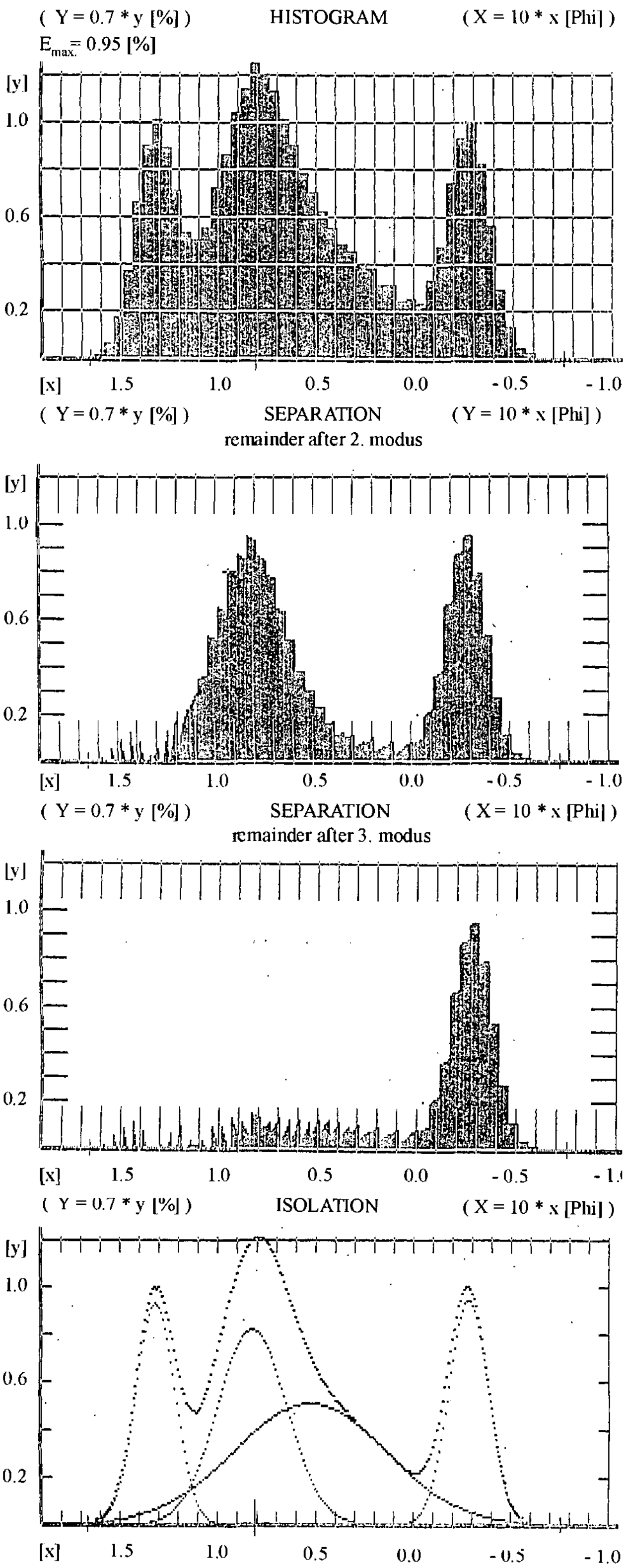


Fig. 5a–d. Process of isolation of a 4-modus, composite density function; a) histogram of the composite denstity function determined from the measurement data, b) residual function resulting from the separating-process after modus 2 has been isolated, c) residual function resulting from the separating process after modus 3 has been isolated, d) the substituting function of the isolated 4 modus, including the combined function
Y. Absolute value of the amplitude, in %, y. Value of amplitude, in relative unit, X. Absolute value grain size, in Phi, x. Grain size, in relative unit, E_{max}. Peak value of the composite function

5a–d. ábra. Négy módusú minta izolációja gyakorisági értékek alapján; a) a mért gyakorisági értékek hisztogramja, b) a maradék függvény a második módus leválasztása után, c) a maradék függvény a harmadik függvény leválasztása után, d) a négy módus izolációja a burkoló görbével
Y. Az amplitúdó abszolút értéke %-ban, y. Az amplitúdó értéke relatív egységben, X. A szemcseméret abszolút értéke F-értékben, x. Szemcseméret relatív egységben, E_{max}. A függvény értéke.

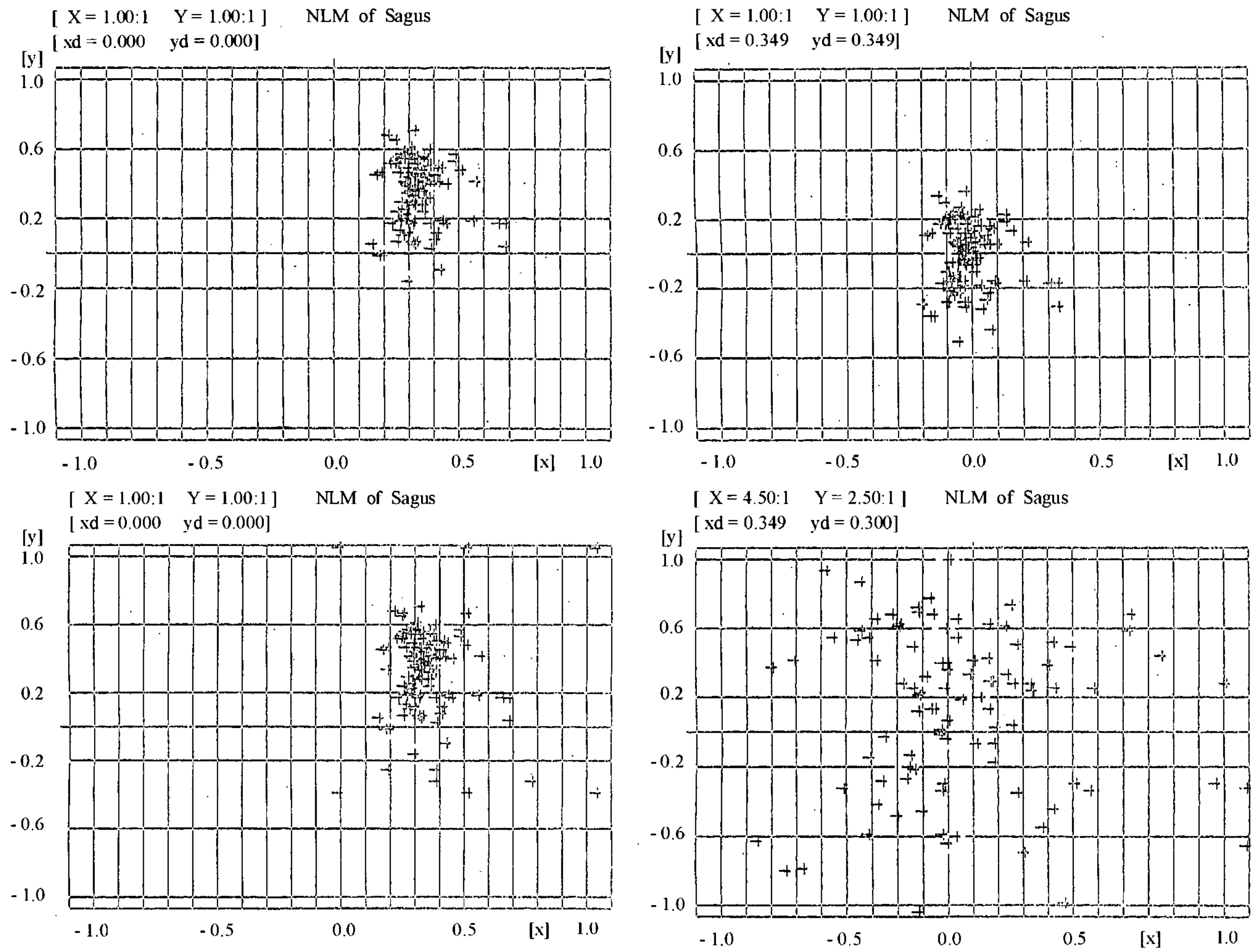


Fig. 6a–d. Results from the SNLM analysis of a mixed type data set (100 samples); a) a graphic diagram of SNLM data calculated from the samples, b) a combined display of data concerning samples and the system of points matched to the surface of the examined area, c) a shifting of the graphic picture by relative units xd=0.35 and yd=0.35, d) a displacement of the graphic picture (xd=0.35, yd=0.30 including a subsequent magnification of X=4.5 and Y=2.5)

X. Ratio of magnification (reduction) in direction X, Y. Ratio of magnification (reduction) in direction Y, xd. Shifting the origo by a value of xd in direction x, yd. Shifting the origo by a value of yd in direction y

6a–d. ábra. 100 darab, vegyes genetikájú minta SNLM-diagramja; a) a minták SNLM-diagramja, b) a minták SNLM-diagramja, a matematikai felület rögzítő pontjainak feltüntetésével, c) a pontfelhő elcsúsztatása x=0,35 és y=0,35 relatív értékkel, d) a pontfelhő csúsztatása x=0,35 és y=0,30 relatív egységgel, valamint nagyítása X=4,5-szörös és Y=2,5-szeres mértékben

X. a nagyítás (kicsinyítés) mértéke X irányban, Y. a nagyítás (kicsinyítés) mértéke Y irányban, xd. csúsztatás az origó felé xd értékkel, yd. csúsztatás az origó felé yd értékkel

The calculations can be related to statistical data concerning granulometric composition (average grain size, standard deviation, slope and peakedness), to highlighted grain values (C — 99%, M — 50% and L — 1%), and to other chemical features (such as carbonate content, pH value etc.). Of course, the involvement of the rest of chemical features still not scaled according to those described before into the examination is only recommended and advisable for internal follow-up examinations aiming at a further refinement of groups of identical character.

Sagus supplies program engineering tools, namely, graphic shifting, magnification and reduction, to allow for the review of the interior of grouping of individuals of identical character.

Experience on the application of Sagus, on the bases of the sedimentary petrological examinations of the Gödöllő Pilot Area

by T. MÜLLER

In the year 1989, agrogeological investigations were made at the Gödöllő Arboretum by the Agrogeological Department of the Geological Institute of Hungary (Fig. 7). In these investigations, a total of 50 boreholes with a depth ranging from 2 to 10 m were drilled and sampled.

The aim of these investigations were to provide a comprehensive agrogeological study of the area concerned, particularly, to have a better knowledge of the relation-

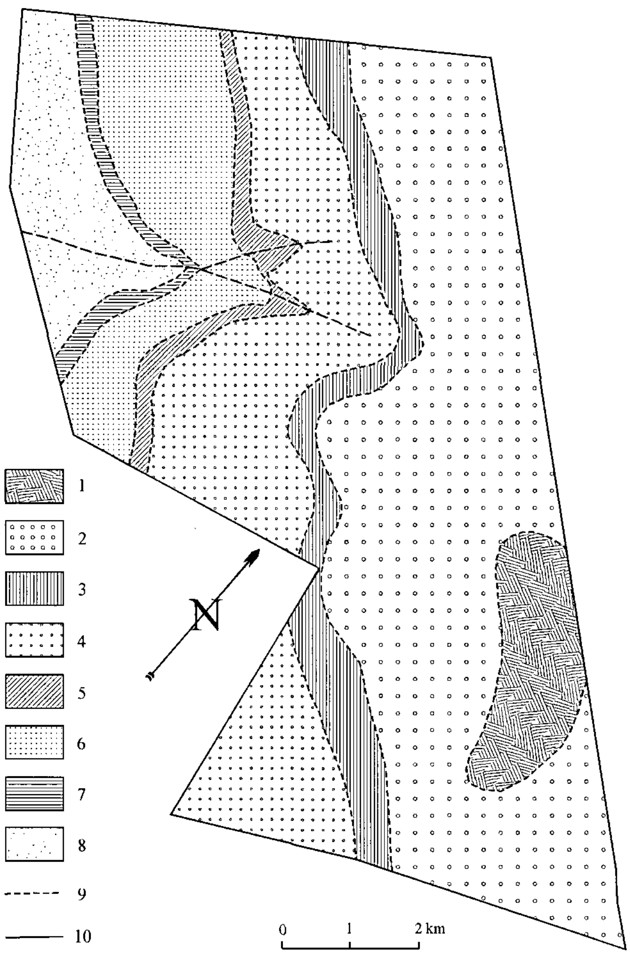


Fig. 7. An uncovered geological map of the Gödöllő Arboretum (after KALMÁR 1991, simplified)
1. Rust brown forest soil (uninterrupted), 2. "Cover" sand, 3. "Main" silty clay, 4. "Main" sand, 5. Argillaceous silt, 6. Silty, argillaceous ("middle") sand, 7. Argillaceous, sandy silt, 8. "Footwall" sand, 9. Gully, 10. Boundaries of the Arboretum

7. ábra. A Gödöllői Arborétum fedetlen földtani térképe (KALMÁR [1991] után, egyszerűsítve)
1. Összefüggő (rozsdabarna erdei) talajborítás, 2. „Fedőhomok", 3. „Fő" kőzetlisztes agyag, 4. „Fő" homok, 5. Agyagos aleurit, 6. Kőzetlisztes, agyagos („köztes") homok, 7. Agyagos, homokos aleurit, 8. „Fekühomok", 9. Vízmosás, 10. Az arborétum határa

ships of the complex system of bedrock–groundwater–soil. The upper soil level, the lower soil level, the level where groundwater occurs, and the zone permanently inundated by groundwater were sampled. The samples were subjected to mineralogical, petrological and sedimentological tests. In 1991 and 1992, J. KALMÁR, based on the result obtained, also including his own observations, made a description of the geology and stratigraphy of the Gödöllő Pilot Area. Using the modus analyzing module of the Sagus program, the geological and stratigraphic model of the area concerned was added.

The role of mode analysis in the examination of unconsolidated sediments

The degree in which the grains of detrital sedimentary deposits are sorted depends on several factors. Of them, the major ones include the grade of the initial material, the type of medium performing the transport, the magnitude of energy of the transporting medium. All the aforesaid, varying in time and space, clearly determine, at a particular area, the grain distribution of a sediment.

Although the grain distribution for a non-negligible part of detrital sedimentary rocks can be approximated with a lognormal density function, it is a more frequent phenomenon that the actual distribution is given by several components each of lognormal distribution, and is formed by superimposing each bell-shaped curves.

In geological aspect, each lognormal distribution means a formation developed during a short period measured on a geological scale, with identical physical, physico-chemical and energetical parameters. This formation (distribution, fraction) created under identical and almost-permanent genetical conditions is called population. By isolating each population with Gauss distribution, and interpreting their statistical parameters, would allow us to give a reconstruction of the conditions under which the sample with a composite distribution was accumulated, or developed, thereby giving a more precise geological picture thereof.

Hereinafter, the geological description of the Gödöllő Pilot Area and the results from the modus test performed using Sagus shall be given together when describing each formation.

The geological structure of the Gödöllő Pilot Area, including results from the granulometric composition analysis

The total thickness of the examined unconsolidated sedimentary sequence is approx. 130 m. The sequence is divided to seven formations that can also be traced in the nearby mapping boreholes. Here is a brief macroscopic description of each formation, including a related computer-based evaluation:

1. Underlying sand. Fine- to medium-grained sand, with a thin argillaceous intercalation. At some sites, its thickness exceeds 35 m. As shown by Sagus examinations, four populations can be observed in the formation. Clay with a mean grain diameter of 10 Phi is observed in a subordinate amount and is sharply isolated in the diagram. The major constituents are two sand populations, with a mean grain diameter of 4 and 5 Phi, respectively. The locations of their maximum grain diameter are due to a slight alteration. In a few samples, small maxima can be observed of small gravels probable.

2. Argillaceous, sandy silt. Thickness: 4 to 10 m. Two population can be observed in the formation. The first one is clay with a mean grain diameter of 9 to 10 Phi, whereas the other one is sand with a mean grain diameter of 5 Phi. The computer-based analysis does not support the presence of a larger amount of silt.

3. Medium-grained sand. Its major part is medium- to fine-grained sand. In its lower part, thin limestone stripe intercalations are observed. It overlies, with conformity, the argillaceous, sandy silt. It has a thickness of 13 to 16

m. Unfortunately, the determination of the precise number of populations failed, due to the insufficient amount of samples. The number of populations detectable in the formation is 4, or 5, however, the number of those actually included must be less. The bed is accompanied by a clay population with a mean grain diameter of 3 to 5 Phi (Fig. 8). As shown by the computer-based analysis, many transitions can be detected between the two major mean grain diameters. In several samples, a powerful but irregularly-shaped mean grain diameter maximum can be observed near the value of –2 Phi. We cannot give a sure explanation to it but assume that the grinding of thin limestone strip beds during the drilling action may be concerned, and its splints are likely to cause this irregularly-shaped peak to appear.

4. Argillaceous silt. In its upper part, silty sand and sandstone and limestone beds can be observed. It overlies, with conformity, the medium-grained sand bed. It has a thickness of 5 to 9 m. In the computer-based evaluation, three populations were separated. The clay has a mean grain diameter ranging from 10 to 11 Phi. The lower part of the formation is featured by the dominance of clay which is present here in an amount twice the amount of the other two populations. However, in the upper zone, its amount is subordinate, here and there, as compared to the other two popullations with a grain diameter of 7 and 5 Phi, respectively. This confirms the part of the macroscopic description, relating to the large amount of silty sand.

5. "Main" sand bed. According to the macroscopic description, its upper and lower parts are fine-graded and medium-grained, respectively, sand. It overlies, with no hiatus, the central silty clay, and has a thickness of approx. 22 m. As shown by the computer-based analysis, this one represents a very complex formation in which at least four populations can be observed. Of them, a clay population with a diameter of 10 Phi is always present, although with a varying and subordinate amount, in the sequence. The two main sand populations have an average mean grain diameter of 2.5 and 5 Phi, respectively, but it can only be considered as an average, since in this range each mean grain size value strongly varies from sample to sample, that is, continuous series of transitions can be observed between the two extreme values (Fig. 9). The mentioned fourth population is assumed to represent an intermediate grain diameter in the range 2.5 and 5 phi which can, although, be separated from the rest by using a computer but its existence is doubtful in regard to distribution analysis.

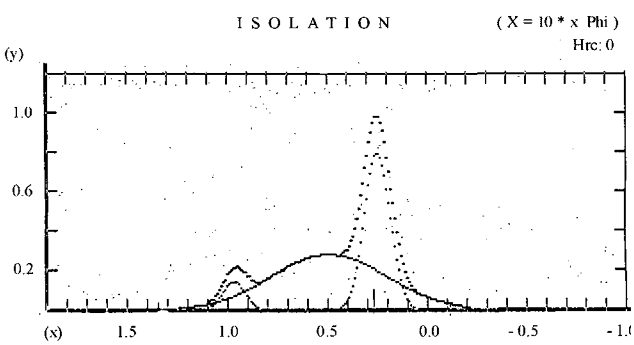


Fig. 8. The frequency distribution for the three sand populations (clay and two medium-grained sand populations) of the medium-grained sand (Gödöllő Pilot Area, borehole 11, sample 2)

8. ábra. A középszemű homok három szemcsepopulációjának (agyag és két középszemű homok) gyakorisági görbéje (gödöllői mintaterület, 11. sz. fúrás, 2. minta)

6. "Main" silty clay. It overlies the "main" sand bed without interuption. It has thickness of 4 to 8 m. The main population is clay with a mean average grain diameter of 10 Phi. A sand population with a mean grain size of 6 Phi is also present in a relatively large amount. Its amount, although it varies, is more, anyway, than justified by the macroscopic description (Fig. 10).

7. "Cover" sand bed. Its main constituent is a medium-grained sand in which three intercalations can be traced vertically. It has a thickness attaining even 23 m. The formation can be divided into two main populations. The sand that is included in a larger amount has a mean grain diameter of 6 Phi, whereas the clay included in a smaller amount has a mean grain size of 9 Phi. It can be stated that the amount of the sand is approx. 3 to 4 times the amount

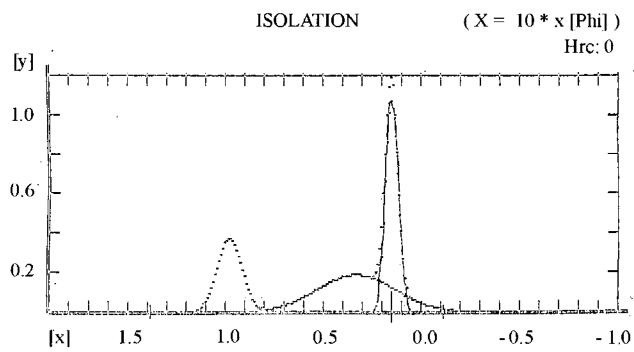


Fig. 9. The frequency distribution for the three populations (clay, fine-grained and medium-grained sand) of the "main" sand (Gödöllő Pilot Area, borehole 27, sample 7)

9. ábra. A „főhomok" három szemcsepopulációjának (agyag, finom- és középszemű homok) gyakorisági görbéje (gödöllői mintaterület, 27. sz. fúrás, 7. minta)

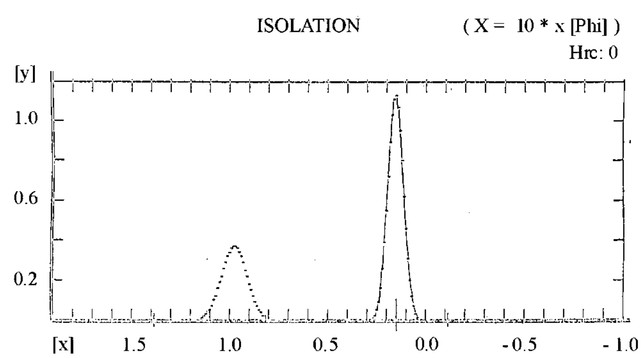


Fig. 10. The frequency distribution for the two populations (clay and medium-grained sand) of the "main" silty clay (Gödöllő Pilot Area, borehole 5, sample 6)

10. ábra. A „fő kőzetlisztes agyag" két szemcsepopulációjának (agyag és középszemű homok) gyakorisági görbéje (gödöllői mintaterület, 5. sz. fúrás, 6. minta)

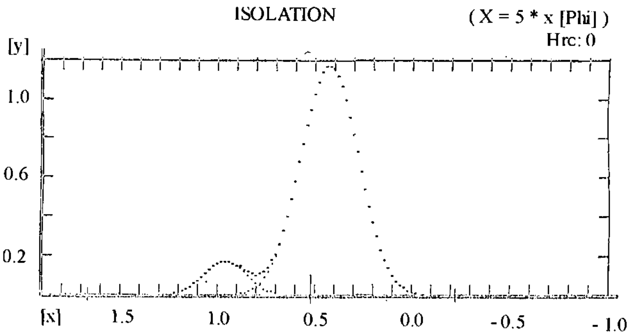


Fig. 11. The frequency distribution for the two major populations (clay and medium-grained sand) of the "cover" sand (Gödöllő Pilot Area, borehole 3, sample 4)

11. ábra. A „fedő homok" két szemcsepopulációjának (agyag és középszemű homok) gyakorisági görbéje (gödöllői mintaterület, 3. sz. fúrás, 4. minta)
X. abszolút szemcseméret Φ-értékben, Hrc. hibakód

of clay (Fig. 11). The distributions are approximately identical with the distributions of the "main" sand. The main difference is the higher clay content of the overlying bed.

The computer-based modus analysis of samples from the Gödöllő Pilot Area has highlighted the major advantages offered by this method. It has been clearly found so that the composite samples consisting of several populations can be separated into each population, with a high security, and that its main features (mean grain size, standard deviation, the proportions compared to the other populations) can be read. In samples located one above the other in the same formation, the permanent modification of each population in response to the effect of varying sedimentary parameters, that is, the variations of the distribution of a population in time and space could be traced. Accordingly, we have a high sensitivity method that allows us to observe the decreasing, or increasing tendency of the amplitude of a population, and the merging of a population into another population, or the emergence of two new populations from one. All these greatly help us to have a better understanding of the changes in facies of detrital sedimentary rocks, the merging of a facies into another, or their separation.

Issues on the application of SNLM in facies analysis

by GY. GYURICZA

In sedimentological investigations, it is a serious problem that the direct application of the basically accepted FOLK–WARD and MCCAMMON's statistical parameters in facies analysis is very limited. The majority of the numerous two-variable diagrams worked out hitherto are suitable for use mainly in a particular geological environment, generally, in the separation of two specified facies. In case of an application associated with domestic examples, in most cases the original facies boundaries needs changing (for instance, CHIKÁN 1991). These uncertainties are generally known, therefore, out of the two-variable diagrams, only the simplest C/M diagram with the least chances for a mistake, including its derived versions have been widely used, thus in the domestic practice as well (BÉRCZI, BALOGH 1991).

The most efficient way of checking and targeted development of the sedimentological applications of the mode testing functions of the Sagus system and the SNLM is the detailed examination of samples from well distinguishable, unconsolidated sedimentary facies having typical and relatively stable features. For this purpose, first a total of 98 grain composition curves, considered to be typical of driftsands in Hungary were examined. The statistical average values obtained from the evaluation are shown in Table 2.

Table 2 — 2. táblázat

Statistical average values for the granulometric composition of representative samples from driftsands in Hungary
Reprezentatív hazai futóhomok minták szemcseösszetételének statisztikai átlagai

Group of Samples	D_{mm}	D_{Φ}	δ_I	S_k	K_G
Group 1 (80 samples)	0.181	2.58	0.583	0.047	1.14
Group 2 (15 samples)	0.157	2.76	0.521	0.091	1.28
Group 3 (3 samples)	0.185	2.55	0.626	-0.201	1.28

The groups have to be separated due to the various screen series used in the examinations — A csoportok szétválasztása a vizsgálatnál használt különböző szitasorok miatt volt szükséges.

Legends: D_{mm} — mean grain size, in mm — közepes szemcseméret mm-ben; D_{Φ} — mean grain size, in Φ — közepes szemcseméret Φ-ben; δ_I — standard deviation — szórás; S_K — slope — ferdeség; K_G — peakedness — csúcsosság.

The cumulative curves of samples show a few deviations, they usually indicate a single mode, with their slope indicating a similar peakedness value. In the examination of histograms, it was found so, in almost every case, that the measure scale applied in the measurement is too sparse. Due to the typical features of spline approximation (PÁSZTOR 1988) there is a danger in this case that even the samples which are sorted the best show several modus. At this time the histogram shows a readout of the number of screens applied, and the approx. hole size. The mode parameters were determinded on the basis of the histograms, with a definition of 0.5 Phi, of the samples (Fig. 12a).

Although slight deviations were frequently observed due to the variation of standard deviation values, the mode picture obtained was similiar for the major part of drift sand samples studied. (Fig.12b). For the histograms, the variability was higher; only a few samples with such a symmetrical distribution was found.

In the detailed examinations of histograms of 32 drift sand samples taken from the Danube-Tisza Interfluve, it has been found so that for the apparently agreeing diagrams the values of the conventional slope (Sk-) parameter (FOLK, WARD 1957) showed too large deviations with respect to one another in many cases. In some cases, even a difference in sign was also manifested. For the drift-sand, the distributions are almost precisely symmetrical, therefore the

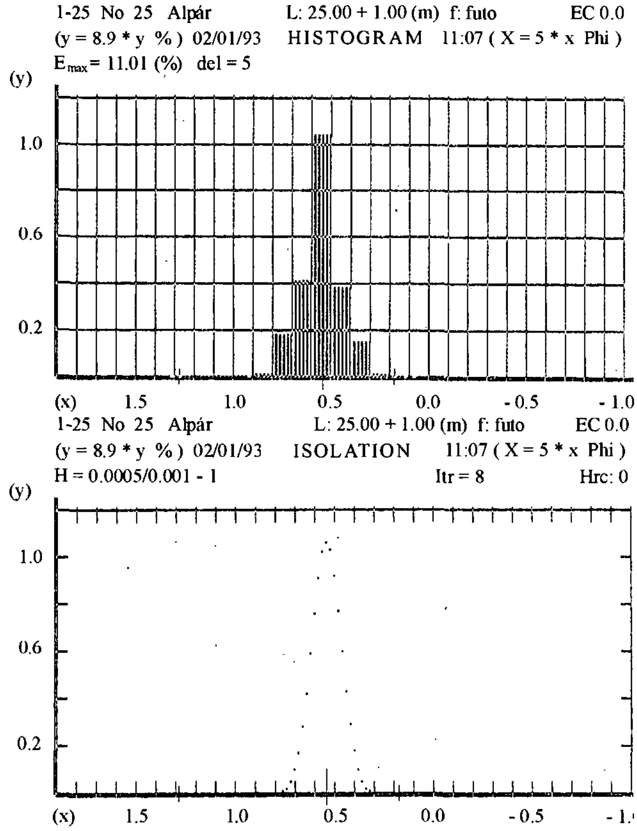


Fig. 12a–b. Histogram [a] and modus picture [b] for a sample from a driftsand

12a–b. ábra. Egy futóhomok minta hisztogramja [a] és móduszképe [b]

slope fluctuates about 0, thus, it is sensible to respond even too small deviations. When checking the evaluation using bell type, or even cumulative curves of samples corresponding to various facies, this phenomenon is not striking. However, for samples that are so similar to one another, we do not believe that this is allowed in the evaluation of histograms. Therefore, a major goal of the development of the Sagus system was to establish a parameter which relates to the symmetry conditions of distribution better than the slope parameter (Sk) does. The symmetrical factor As described formerly seems to meet these requirements.

Irrespective of the inaccuracies, it is sure that the increase in slope value with respect to the symmetrical one would allow us to draw conclusion on the mode, that is, the grain population the rock being examined consists of (Figs. 13a and 13b). For the majority of cases like this, the measurement data do not allow for the direct detection of the several modes. Thus, a further objective of great importance is to find the limit values of slope, or symmetry parameters which clearly indicate the number, and possibly, the position of each mode. Finding a succesful solution to this problem may lead, at the same time, to find a computer-based technique for the automatic isolation of each modes.

After the analysis of grain composition curves, the driftsand samples were plotted in an SNLM diagram (Fig.14). As shown, the samples that seem, macroscopically, nearly completely identical, are located with a definite density around values x = 0–0.15 and y = 0.1–0.2. (For SAMMON's NLM, the points appear with an alignment to the limit values of the positive quadrant of the diagram, with a scattering covering an area of some 1/8 part of the diagram (Fig. 4). For the SNLM representation, it is a phenomenon of major importance that here the position of

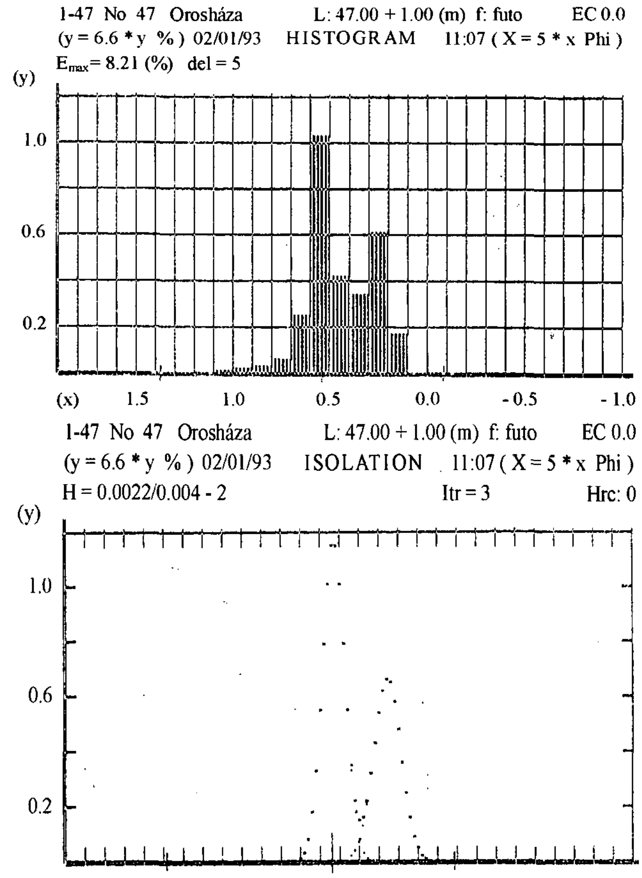


Fig. 13a–b. Histogram [a] and modus picture [b] for a sample from the sand at Orosháza (Békés county, SE Hungary)

13a–b. ábra. Egy orosházi homokminta hisztogramja [a] és móduszképe [b]

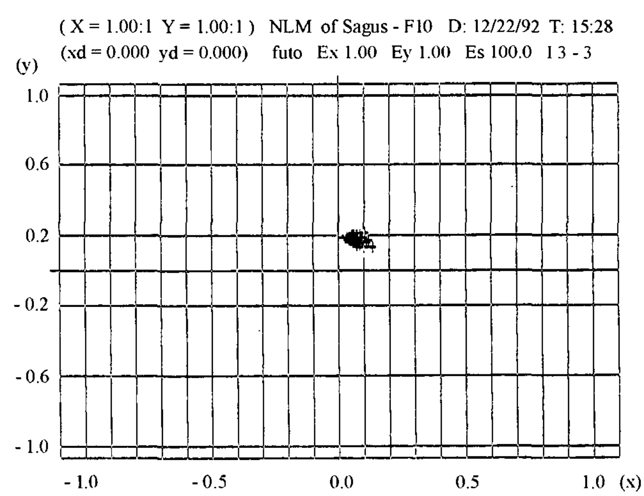


Fig. 14. An SNLM diagram of driftsands in Hungary

14. ábra. A magyarországi futóhomokok SNLM-diagramja

each sample is fully independent and can only be varied by modifying the scale.

After revealing the cluster of points (by shifting the cluster of points in the proper direction and in the proper degree, then by magnifying it, with the original scale leaving unchanged; Fig. 15) a definite internal structure becomes visible. In our diagram, the sample arrangement depends on the mean grain size (due to the typical features of spline approximation the x-axis) and the variance value (its decrease causes the point to move to the left along the y-axis). Due to the minor values of fluctuations and the narrow interval, the precise tracking of variations of slope and peakedness failed. For the set of samples from driftsand, the SNLM diagram functions almost as a two-variable diagram. The sensitiviy of the diagram to these values can be increased by multiplying the slope and peakedness parameters by a proper constant.

Either the position of each sample with respect to the rest, within the cluster of points, or the relationship of the SNLM coordinates to the sites of occurrence have not been studied in detail yet. We are sure that at some junctions with greater density, the samples from a particular area show a different frequency. For instance, the major part of samples from the Danube–Tisza Interfluve and that of samples from Nyírség (region in the north-eastern part of Hungary) are located at different positions. This phenomenon cannot be linked with either a difference in measuring methods, or the difference of the sampling method applied. In addition, it is very easy to isolate the different formations, thus, for instance, a sample marked A that is the same as the clay sample from Orosháza shown in Fig. 13, contains, in addition to a grain population typical of driftsand, also a subordinate amount of coarse, presumably fluvial sand.

Since the major part of the unconsolidated sedimentary facies we have first examined is a formation with a well sorted, easy to separate modus, it can be stated that any sediment found in this area of the diagram is driftsand, or a sequence accumulated by the wind. Of course, our statement holds true only if the positions of samples of another facies falls to another position in the diagram. To examine it, the samples were selected so that the material be similarly uniform, and preferably, well sorted.

It is known to us that the energy of transporting medium is less for loess than for driftsand. However, the grain boundary may provide a wider range due to the variable accumulation terrain, the later soil development and weathering.

To control it, a total of 291 samples from 13 loess profiles taken up in the Hajdúság and Bodrogköz region (NE Hungary) were examined. Of course, the statistical parameters for the average values essentially differ from those of driftsand. Average values for a loess wall at the Debrecen Brickyard are, for instance, as follows: D_{mm}: 0.037, D_{Φ}: 5.618, δ 1:1.941, S_k: 0.414, K_G: 0.974. The greatest differences can be observed at the medium grain size and variance values. The reason for the variation of the latter is that the curves are bimodal; in addition to a typical sand fraction, also a marked grain population featured by the dominance of silt is included therein. Not the individual samples but the particular logs can be considered to be typical, therefore, we deemed that it was worth of comparing them with driftsand.

Of the SNLM diagrams of logs examined, an SNLM diagram in which the diversity of samples was much greater than in the rest of diagrams will be shown (Fig.16). The density of cluster of points is appropriate, that is, the granulometric composition of the particular group of samples is relatively homogenous. A fact of great importance is that the cluster of points for loess is found relatively away from the cluster of points of the driftsand (Fig. 14), despite the considerable sand content of some samples. The approx. horizontal elongation of the cluster of points results from the presence of the two modes and the quantitative relationship between the two grain populations.

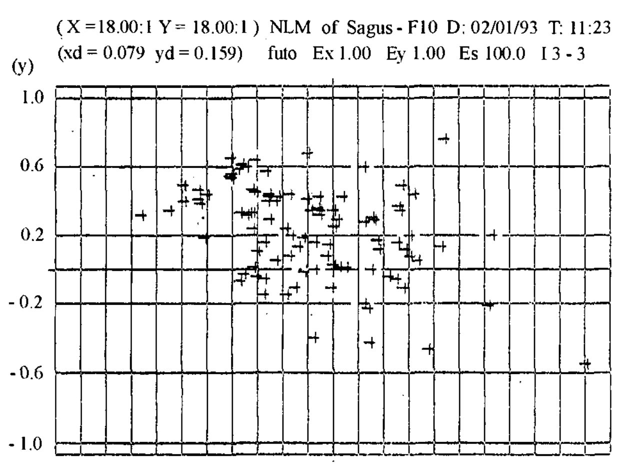


Fig. 15. An exposure (a magnification of 18×) of a cluster of points produced by applying SNLM procedure on samples from driftsands in Hungary

15. ábra. A magyarországi futóhomokok SNLM-eljárással előállított pontfelhőjének feltárása (18-szoros nagyítás)

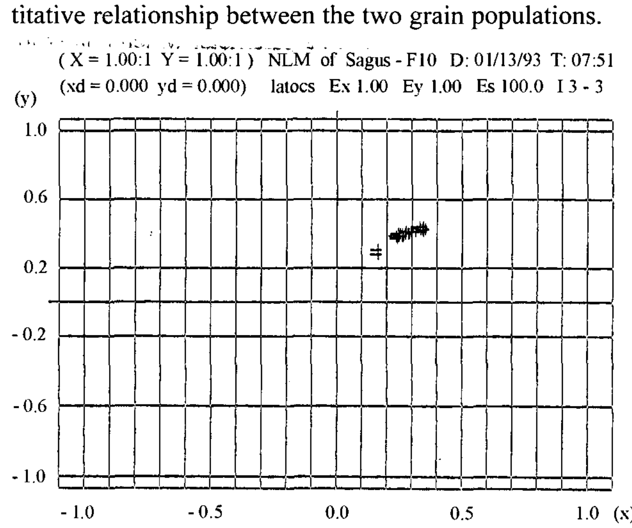


Fig. 16. An SNLM diagram of samples from loess exposure near Látókép csárda (Hajdú-Bihar County, Hungary)

16. ábra. A látóképi csárda (Hajdú-Bihar megye) közelében lévő löszfeltárás mintáinak SNLM-diagramja

The diagram in Fig. 17 shows samples of a sequence that contains no loess. However, in this case the major part of samples contains various silt fractions too. Based thereon, it can be stated that the SNLM diagram, in its present status, in regard to facies analysis, is suitable for separating single-mode samples, that is, actually grain populations.

Of course, the SNLM representation of multi-mode samples can also be implemented but owing to the fact that in this case the rules concerning the location of each point are much more complicated than in the case of lognormal distributions, the information supplied by these diagrams can be interpreted, for the time being, only locally. Thus, the apparent advance with respect to the former two-variable diagrams is only that each size range of granulometric composition can be represented. However, the present SNLM only utilizes a fraction of its capacity. Despite this, it is partially suitable, even today, for separating samples of composite distribution. Such a case is shown in Fig. 6c which shows an SNLM diagram for borehole Zubogy 1. That contains 102 samples from a Lower Pannonian delta-sediment, and the evaluation can be performed when the field sequence is known.

So, the question is whether the Sagus program system can be made suitable for performing a computer-based separation of various unconsolidated sediment facies. Based on the above results, it is highly probable, and the way leading there, that is, a further development of Sagus in this direction is very clear. Its major stages are as follows:

— Separating the deposits having a non-lognormal distribution, into several modes, and calculating the mean grain size and the variance, handling each grain population as an independent sample.

— Determining the typical grain populations for sediment facies with non-lognormal distributions, including the determination of the quantitative ratios with respect to one another. This ratio, with a proper weighting, should be applied as the third dimension of SNLM.

— Incorporating the carbonate content of deposits into the diagram (in the form of either dolomite and calcite separately, or as a total carbonate), because this, in addition to the granulometric composition, may represent a major feature of the particular facies.

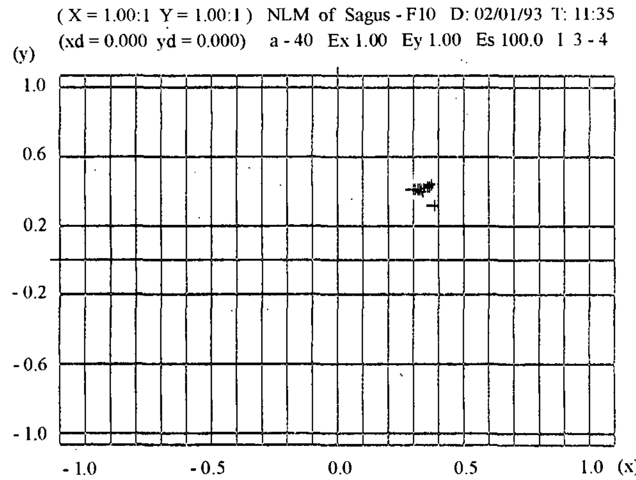


Fig. 17. An SNLM diagram of samples from follow-up borehole A-40 drilled at Gödöllő

17. ábra. A gödöllői A-40 sz. sekélyfúrás mintáinak SNLM-diagramja

Any unconsolidated deposit type has the parameters that are typical of a certain, or several sedimentary facies and, based thereupon, can be clearly separated from any other facies. Since NLM is capable of projecting a few dozens of parameters (dimensions) onto a plane, this method is feasible. However, it can be proved that the proper weighting of several tens of parameters means a too complicated job. Moreover, every parameter ought to be given for every facies which is unnecessary, therefore, the inverse-NLM parameter number needs an optimatization, that is, ensuring as precise separation as possible by comparing as small number of features as possible.

At the present stage of Sagus development, it seems to be advisable to use, later, instead of the formerly used two-variable diagrams, an SNLM diagram processing the mean grain size and variance of a grain population, the quantitative and qualitative interrelationships of grain populations in the sample concerned, and the carbonate content. It is the proper selection and weighting of these parameters that represents an advance toward a computer-based facies analysis based on granulometric composition.

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A SAGUS PROGRAMRENDSZER FEJLESZTÉSI EREDMÉNYEI ÉS ALKALMAZÁSÁNAK LEHETŐSÉGEI A GEOLÓGIAI GYAKORLATBAN

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Tárgyszavak: Sagus programrendszer, geológiai alkalmazás

ETO: 519.688:550.84 519.688:631.42

Az elmúlt évek során az Intézetben — külső résztvevők közreműködésével — kifejlesztettük a laza üledékek szemcseösszetételi elemzésére alkalmas Sagus programrendszert. Ennek alap-algoritmusa a Pásztor Z. által a szemcse-összetételi görbék szerkesztésére alkalmazott spline interpoláció, melynek további finomítása — a görbe simítása — a korábbinál érzékenyebb matematikai eljárások alkalmazását teszi lehetővé. Így pl. a módus-vizsgálat kisebb méréssűrűség mellett is elvégezhető és a ferdeség-paraméter módosításával közelebb kerültünk az eljárás automatizálásához. Ugyancsak jelentős az előrelépés a nem-lineáris vetítés terén; itt a hagyományos eljárás üledék–paraméter skálával történt bővítése és az egyedi vizsgálat bevezetése alkalmassá teszi a rendszert üledékfáciesek értékelésére.

A Sagus programrendszer gyakorlati alkalmazásának lehetőségeit a gödöllői mintaterület rétegeinek elemzésén keresztül mutatjuk be. Ennél a kiértékelésnél a program móduselemző eljárása adta lehetőségeket használtuk ki. A módosított NLM, azaz SNLM hasznosságát nagy számú futóhomok és lösz minta értékelésével demonstráltuk. A bemutatott példák a program fáciesanalitikai alkalmazhatóságát bizonyítják.

ANN. REP. OF THE GEOLOGICAL INSTITUTE OF HUNGARY, 1992–1993/II: 159–161 (1999)

THE INCORRECT CALCULATION OF RANK CORRELATION BY SOME STATISTICAL PROGRAMS

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Manuscript received in 1994.

Keywords: statistical programs, Rank correlation, geological data

UDC: 519.688:550.4 519.23:550.4

Non-parametric procedures play an important role in the statistical evaluation of geological data. Although it is possible to use the SPSS PC+, SYSTAT and SX program packages to calculate various rank correlation coefficients, these packages do not give correct results unless each value in each data sequence to be processed is different. Should there be any identical values, the coefficients will be subject to errors, the type and magnitude of which are package specific. The results supplied by the SPSS PC+ and SYSTAT systems have correct signs but increased absolute values, thus they may indicate that weaker relationships are significant. The results supplied by SX show a positive systematic error which may cause the sign to change in extreme (but not rare) cases. An analysis of the distortions may allow us to draw conclusions about the deficiencies of the applied algorithms. The problem can be solved by the use of GEOSPION, a package originally developed for agrogeology. (This paper is part of the Geochemistry project at the Geological Institute of Hungary.)

Introduction

In the practice of geology, we rarely deal with statistical distributions that are of regular shape, like the normal distribution, or other distributions that can be transformed into the normal. Such regular distributions are applicable under specific conditions only. For instance, in the case of a system in equilibrium. Even so, an originally regular distribution shape may be substantially distorted by diagenetic and surface alteration processes. It is not a coincidence therefore that techniques of robust statistics play an increasingly important role in geological data processing (STEINER 1990).

Regrettably, rank methods are not yet widely used in those areas of sciences which are relatively well endowed with funds. It is a sad fact that this also applies to geology. Thus, it is not surprising that these procedures did not get the due attention of those developing of statistical program packages. I examined, SPSS PC+, a commercial package system used as a standard system at the Geological Institute of Hungary, and two other program packages, SYSTAT and SX. All three calculate both the Spearman and Kendall rank correlation coefficients incorrectly, although with an error of varying degree and character.

Reasons for the errors

The problem is due, in every case, to the existence of ties of identical values leading to identical ranks. The accepted procedure is to assign identical, so-called average rank figures to each identical value (HOLLANDER, WOLFE 1973). Thus, the rank figures for an array of 5 elements consisting of the values of 8, 7, 3, 3, 2 should be 1, 2, 3.5, 3.5 and 5. If arranged in reverse order, they would be 5, 4, 2.5, 2.5, and 1. However, it is easy to prove that this procedure will lead to a reduction of variance, as compared to an array of rank of the all different values of 1, 2, 3, 4, and 5. If this difference is ignored it will necessarily distort the results. Even some, otherwise excellent, mathematical statistics handbooks fail to mention this topic (KÖVES, PÁRNICZKY 1981). It is clear that degree of distortion is increasing with the number of ties. Then the apparent "strength" of relations we aim to detect will no longer depend on the actual relations between the variables alone, but also on the resolution capacity of the method of analysis. If sophisticated multidimensional analysis techniques (such as principal component analysis and factor analysis) are performed using the biased correlation coefficients they may yield completely false results that are far from reality. A naive researcher misled by the indicated high significance values will get into serious trouble when proper interpretation is called for. The basic formula of the Spearman rank correlation coefficient:

$$r = 1 - \frac{6 * \sum d_i^2}{n^3 - n} \qquad (1)$$

where:

n — the number of samples,

d_i — the difference of ranks between the two variables in the i-th sample.

When there are ties, we have to add a tie correction to each d_i^2 term in numerator (1). The tie correction is (SOLOVOV et al. 1978).

$$M = Mx + My = \frac{\sum\left(m_j x^3 - m_j x\right) + \sum\left(m_k y^3 - m_k y\right)}{12} \qquad (2)$$

where:

$m_j x$ — number of occurrences of the j-th value in the variable,

$m_k y$ — number of occurrences of the k-th value in the variable y.

Other correction procedures (SIKOS 1984) modify the denominator of the original fraction instead of the numerator. It is obvious that the higher the proportion of ties within the total number of samples, the greater the role the correction of ties plays in the coefficient, especially, when the majority of the ties occur at the same value.

In the geochemical practice, a typical (and very frequent) example of this is represented by analysis results below the detection limit. The situation is aggravated by semi-quantitative analysis techniques, because in this case the measurements obtained on sets of several thousands samples may take only 5 to 15 possible values (even these can be distributed rather unevenly).

Ignoring the problem of ties, SPSS PC+ and SYSTAT interpret the Spearman coefficient as a linear correlation coefficient of rank numbers (SYSTAT 1984, SPSS PC+ 1990). Should there be no ties, both of them can yield exact results, and so can SX. If there are ties then the computed results, although they have correct signs, will have increased absolute values (moved from 0 towards +1 and −1, respectively). For these distorted values, significance cannot be evaluated. The SX program package —as described in its manual— should work on the basis of similar principles. As shown, test calculations performed to show the character and degree of distortions seem to disprove this assumption.

Test calculations

Calculations were performed using the test data set shown in Table 1.

As shown in Table 1, input data values were set to be identical with the average rank figures that can be formed using them. Consequently, the values of both the Pearson and Spearman correlation coefficients should be the same when calculated by any of the three tested program packages. For SPSS PC+ and SYSTAT systems, both kinds of results are indeed the same, due to the fact that the input data are identical (see Table 2).

Calculating the linear correlation using the SX program yields the same values. However, the results obtained when calculating Spearman's coefficient are surprising (see Table 3).

Table 1 — 1. táblázat

Test input data — Alapadatok

No.	A	B	C	D	E	F	G
1	1	13	1	13	12	2	8
2	2	12	7	7	9	5	7
3	3	11	7	7	9	5	6
4	4	10	7	7	6	8	5
5	5	9	7	7	3	11	4
6	6	8	7	7	3	11	3
7	7	7	7	7	1	13	2
8	8	6	7	7	3	11	1
9	9	5	7	7	6	8	11
10	10	4	7	7	6	8	10
11	11	3	7	7	9	5	9
12	12	2	7	7	12	2	13
13	13	1	13	1	12	2	12

Column header symbols A, B, ..., G indicate variables.

Table 2 — 2. táblázat

Linear and Spearman correlation coefficients calculated using SPSS PC+ and SYSTAT systems

Lineáris és Spearman-féle korrelációs együtthatók az SPSSPC+ és a SYSTAT rendszerek szerint

	B	C	D	E	F	G
A	-1**	.629	-.629	.118	-.118	.511
B		-.629	.629	-.118	.118	-.511
C			-1**			.210
D						-.210
E				-1**	.781	
F						-.781

Table 3 — 3. táblázat

Spearman rank correlation coefficients for variables A through G, when using SX system for the calculations

Az A–G változók Spearman-féle rangkorrelációs együtthatói az SX rendszerben

	B	C	D	E	F	G
A	-1	.698	-.093	.137	-.093	.511
B		-.093	.698	-.093	.137	-.511
C			.209	.324	.324	.434
D				.324	.324	.170
E				-.912	.786	
F						-.742

Thus, the SX program seems to use the basic formula for Spearman rank correlation but it applies no tie correction. This represents a source of a positive systematic error, since the greater the number of ties, the more the value of the coefficient is shifted towards +1. Should both variables contain a great number of ties, then this shift may even cause the sign to change. That is how the obviously negative correlation of variables C and D becomes +0.209. (The correct value should be −1.0 — not that one should trust this value either, considering the rather high degree of uncertainty!). Table 4 presents a summary of (correct) values for the Spearman correlation coefficient.

Table 4 — 4. táblázat

Spearman rank correlation coefficients for variables A through G

Az A–G változók Spearman-féle rangkorrelációs együtthatói

	B	C	D	E	F	G
A	-1	.396	-.396	.115	-.115	.511
B		-.396	.396	-.115	.115	-.511
C			-.396	0	0	.132
D				0	0	-.132
E				-.956	.767	
F						-.767

Similar problems were found in the calculation of Kendall's coefficient (This is not included in the SX program package).

Of all the programs currently used at the Geological Institute of Hungary, we found only one, the RANGKORSAG module (which forms part of the GEOSPION package developed at the Division for Geochemistry), which gives correct values for rank correlation coefficients without any manual correction. However, when the manuscript was submitted, this system only ran on the COMMODORE-64. Consequently, it had a limited capacity and slow speed and it was not connected to multivariate analysis modules. The SPSSPC+ software package developed for Windows has also been tested during the period that has pasted since the completion of the manuscript. The algorithm was not changed, faulty calculations are still given.

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ROSSZUL SZÁMOLNAK RANGKORRELÁCIÓT EGYES STATISZTIKAI PROGRAMOK

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Tárgyszavak: földtani adatok, rangkorreláció, statisztikai értékelés

ETO: 519.688:550.4 519.23:550.4

A földtani adatok statisztikai értékelésének leginkább célra vezető módszere a nemparametrikus eljárások alkalmazása. A Magyarországon meglehetősen elterjedt SPSS PC+ SYSTAT és SX programcsomagok lehetőséget kínálnak ugyan a különféle rangkorrelációs együtthatók számítására, de csak akkor adnak helyes eredményeket, ha a feldolgozott adatsorokban valamennyi számérték különbözik. Ha vannak egyezések, az együtthatókat programfüggő típusú és mértékű hibák terhelik meg. Az SPSS PC+ és SYSTAT rendszerek előjelhelyes, de megemelt abszolút értékű eredményeket szolgáltatnak, tehát gyengébb kapcsolatokat is szignifikánsnak jelezhetnek. Az SX eredményeit viszont pozitív szisztematikus hiba terheli, ami szélsőséges (de nem ritka) esetekben akár előjelváltozást is okozhat. A torzulások elemzésével következtethetünk az alkalmazott algoritmusok hiányosságaira. A kézirat leadása óta eltelt időszakban megkaptuk az SPSSPC+ programcsomag WINDOWS alatt futó változatát is. Az algoritmus nem változott: továbbra is rosszul számol.